DEPARTMENT OF HEALTH AND HUMAN SERVICES

Centers for Disease Control and Prevention

Draft Guideline for Prevention of Intravascular Device-Related Infections: Part 1. "Intravascular Device-Related Infections: An Overview" and Part 2. Recommendations for Prevention of Intravascular Device-Related Infections; Notice of Comment Period

AGENCY: Centers for Disease Control and Prevention (CDC), Public Health Service (PHS), Department of Health and Human Services (DHHS).

ACTION: Notice.

SUMMARY: This notice is a request for review and comment of the draft Guideline for Prevention of Intravascular Device-related Infections. The Guideline consists of two parts: Part 1. "Intravascular Device-related Infections: An Overview" and Part 2. "Recommendations for Prevention of Intravascular Device-related Infections," and was prepared by the Hospital Infection Control Practices Advisory Committee (HICPAC) and the National Center for Infectious Diseases (NCID), CDC.

DATES: Written comments on the draft document must be received on or before October 30, 1995.

ADDRESSES: Comments on this document should be submitted in writing to the CDC, Attention: IV Guideline Information Center, Mailstop E–69, 1600 Clifton Road, NE., Atlanta, Georgia 30333. To order copies of the Federal Register containing the document, contact the U.S. Government Printing Office, Order and Information Desk, Washington, DC 20402–9329, telephone (202) 512–1800. Specify the date of the issue requested and stock number 069–001–00089–1. See page II of the Federal Register for additional ordering and cost information. In addition, the Federal Register containing this draft document may be viewed and photocopied at most libraries designated as U.S. Government Depository Libraries and at many other public and academic libraries that receive the Federal Register throughout the country. The order-desk operator can tell you the location of the U.S. Government Depository Library nearest you.

FOR FURTHER INFORMATION CONTACT: The IV Guideline Information Center, telephone (404) 332–2569.

SUPPLEMENTARY INFORMATION: This 2-part document updates and replaces the previously published CDC Guideline for Prevention of Intravascular Infections (Am J Infect Control 1983;11:183–199). Part 1, "Intravascular Device-related Infections: An Overview," reviews issues relevant to intravascular device-related infections and serves as the background for the consensus recommendations of the Hospital Infection Control Practices Advisory Committee (HICPAC) that are contained in Part 2, "Recommendations for Prevention of Intravascular Device-related Infection."

HICPAC was established in 1991 to provide advice and guidance to the Secretary and the Assistant Secretary for Health, DHHS; the Director, CDC; and the Director, NCID regarding the practice of hospital infection control and strategies for surveillance, prevention, and control of nosocomial infections in U.S. hospitals. The committee also advises CDC on periodic updating of guidelines and other policy statements regarding prevention of nosocomial infections.

The Guideline for Prevention of Intravascular Device-related Infections is the third in a series of CDC guidelines being revised by HICPAC and NCID, CDC.

Dated: September 14, 1995.

Claire V. Broome,

Deputy Director, Centers for Disease Control and Prevention (CDC).

Guideline for Prevention of Intravascular Device-Related Infections

Executive Summary

The revised guideline is designed to reduce the incidence of intravascular device-related infections and provides an overview of the evidence for recommendations considered prudent by consensus of HICPAC members. A working draft of the guideline was reviewed by experts in hospital infection control, internal medicine, pediatrics, and intravenous therapy; however, all recommendations contained in the guideline may not reflect the opinion of all reviewers.

This document focuses largely on the epidemiology, pathogenesis and diagnosis of, and preventive strategies for, infections associated with the intravascular devices most commonly used in health care settings and for which there is adequate scientific data on which to base recommendations for device use and care. Such devices include peripheral venous and arterial catheters, central venous and arterial catheters, peripherally inserted central venous catheters, and pressure monitoring systems. Newer devices (e.g., antimicrobial-impregnated catheters, needleless infusion systems) are also discussed. However, intraaortic balloon pumps, cardiac catheters, pacemakers, and extracorporeal membrane oxygenators are not addressed in this document because there is insufficient scientific data on which to base recommendations for use and care.

The unique circumstances and special considerations related to intravascular device-related infections in pediatric patients and infections associated with parenteral nutrition and hemodialysis will be addressed in separate sections.

Introduction

Intravascular devices are indispensable in modern-day medical practice. However, the use of intravascular devices is frequently complicated by a variety of local and/or systemic infectious complications. Infections related to the use of intravascular devices, particularly catheter-related bloodstream infections, are associated with increased morbidity and mortality, prolonged hospitalization, and increased medical costs.

Part 1, "Intravascular Device-related Infections: An Overview" addresses many of the issues and controversies in intravascular-device use and maintenance. These issues include definitions and diagnosis of catheter-related infection, barrier precautions during catheter insertion, changes of catheters and administration sets, catheter-site care, and the use of prophylactic antimicrobials, flush solutions and anticoagulants. Part 2, "Recommendations for Prevention of Intravascular Device-related Infections" provides consensus recommendations of the HICPAC for the prevention and control of infections related to the use of intravascular devices.

The Guideline for Prevention of Intravascular Device-related Infections is intended for use by personnel who are responsible for surveillance and control of infections in the acute-care, hospital-based setting, but many of the recommendations may be adaptable for use in the outpatient or home-care setting.

Part 1. Intravascular Device-Related Infections: An Overview

Contents

I. Background

Intravascular devices are indispensable in modern-day medical practice. They are used to administer intravenous fluids, medications, blood products, and parenteral nutrition fluids, and to monitor the hemodynamic status of critically ill patients. However, the use of intravascular-devices is frequently complicated by a variety of local and/or systemic infectious complications (see definitions in Table 1), including septic thrombophlebitis, endocarditis, bloodstream infection (BSI), and metastatic infection (e.g., osteomyelitis, endophthalmitis, arthritis) resulting from hematogenous seeding of another body site by a colonized catheter. Catheter-related infections (CRIs), particularly catheter-related BSIs (CR–BSIs), are associated with increased morbidity; mortality of 10%–20%; prolonged hospitalization (mean of 7 days); and increased medical costs, in excess of $6,000 (1988 dollars) per hospitalization.[1–5]

II. Epidemiology

An estimated 200,000 nosocomial BSIs occur each year.[6] During 1980–1989, significant increases were detected in the rates of nosocomial BSI reported from the National Nosocomial Infection Surveillance (NNIS) System hospitals where hospital-wide surveillance was conducted.[7] Reported rates increased by 70%–279%, depending on hospital size and affiliation.

Most nosocomial BSIs are related to the use of an intravascular device, with BSI rates being substantially higher among patients with intravascular devices than among those without such devices.[8] As with overall rates of nosocomial BSI, rates of device-related BSI vary considerably by hospital size, hospital unit/service, and type of device. During the years 1986–1990, NNIS hospitals conducting intensive care unit (ICU) surveillance reported rates of central catheter-related BSI ranging from 2.1 (respiratory ICU) to 30.2 (burn ICU) BSIs per 1,000 central catheter days. Rates of noncentral catheter-related BSI were substantially lower, ranging from 0 (coronary, medical, and medical/surgical ICU) to 2.0 (trauma ICU) BSIs per 1,000 noncentral catheter-days.[8]

The incidence of and potential risk factors for intravascular-device related infections may vary considerably with the type and intended use of the device, and these factors should be considered when selecting a device for use.

In general, intravascular devices can be divided into two broad categories, those used for short-term, or temporary, vascular access and those used for long-term vascular access. Long-term (indwelling) vascular devices usually require surgical insertion, while short-term devices can be inserted percutaneously.

Devices Used for Short-Term Vascular Access

Peripheral venous catheters. Of all intravascular devices, the peripheral venous catheter is the most commonly used. Phlebitis, largely a physicochemical or mechanical rather than infectious phenomenon, remains the most important complication associated with the use of peripheral venous catheters. A number of factors, including type of infusate and catheter material and size, influence a patient's risk for developing phlebitis (Table 2); when phlebitis does occur, the risk of local CRI may be increased.[9–13] However, peripheral venous catheters have rarely been associated with BSI;[9 14–17] this may reflect the short duration of catheterization with these devices.

Peripheral arterial catheters. Peripheral arterial catheters are commonly used in acute-care settings to monitor the hemodynamic status of critically ill patients. Data suggest that peripheral arterial catheters may be associated with a substantially lower risk of local CRI and CR–BSI than are peripheral venous catheters left in place for a comparable length of time.[18] Although the reasons for the differences in rates of CRI associated with these two types of catheters are not clear, arterial catheters may be less prone to colonization than are venous catheters because they are exposed to higher vascular pressures.[19] Factors shown to predispose patients with peripheral arterial catheters to CRI are inflammation at the catheter insertion site, catheterization >4 days, or catheter insertion by cutdown.[20 21] In contrast to peripheral venous catheters, peripheral arterial catheters inserted in the lower extremities, specifically the femoral area, do not clearly pose a greater risk of infection than do peripheral arterial catheters inserted in upper extremities or brachial areas.[22]

In addition to monitoring hemodynamic status, arterial catheters may also be used to administer local intraarterial chemotherapy. Although this is a well-established method for treating metastatic or unresectable tumors, very little has been published on the infectious complications associated with this form of therapy. Maki et al. conducted an epidemiologic investigation of endarteritis associated

with intraarterial chemotherapy administration and identified several risk factors for infection: leukopenia, hypoalbuminemia, prior radiation therapy, difficult catheterization, and repeated manipulation of the catheter.[23]

Midline catheters. Midline catheters are peripherally inserted (into antecubital veins), six-inch elastomer catheters that do not enter central veins, but have recently been used as an alternative to central venous catheterization. Presently, there is little published scientific data on which to assess the infectious risks posed by these newer devices.

Nontunneled central venous catheters (CVCs). CVCs account for an estimated 90% of all catheter-related bloodstream infections[6] and nontunneled (percutaneously-inserted) CVCs are the most commonly used central catheters. Among the factors that influence the risk of infection associated with the use of CVCs are the number of catheter lumens and the site at which the catheter is inserted.

Multilumen CVCs are often preferred by clinicians, because they permit the concurrent administration of various fluids/medications and hemodynamic monitoring among critically ill patients. In nonrandomized trials, multilumen catheters have been associated with a higher risk of infection than have their single-lumen counterparts.[24–26] In two of three randomized trials multilumen catheters were associated with an increased risk of infection.[27–29] Multilumen catheter insertion sites may be particularly prone to infection because of increased trauma at the insertion site and/or because multiple ports increase the frequency of CVC manipulation.[25 26] Although patients with multilumen catheters tend to be more ill, the infection risk found with the use of these catheters may be independent of the patient's underlying disease severity.[28]

In addition to the number of lumens, the site at which a CVC is inserted may play a major role in CVC-related infections. Five of six studies have shown a significantly higher colonization or infection rate with catheters inserted into the internal jugular vein compared with those inserted into the subclavian vein, with a risk ratio as high as 2.7.[30–35] Other risk factors for CVC-related infections include repeated catheterization, presence of a septic focus elsewhere in the body, exposure of the catheter to bacteremia, absence of systemic antimicrobial therapy,[31] duration of catheterization, and type of dressing.[33]

Central arterial catheters. Pulmonary artery catheters (PACs) (i.e., Swan

Ganz[1] catheters) differ from CVCs in that they are inserted through a Teflon introducer and typically remain in place an average of only 3 days. However, they carry many of the same risks and have similar rates of BSI as do other central catheters. Risk factors reported for CRI in patients with PACs include duration of catheterization >3 days,[36] >5 days,[37] or >7 days;[21] colonization of the skin insertion site;[36 38] and catheter insertion in the operating room using submaximal barrier precautions (i.e., gloves, small-fenestrated drape).[36] Site of insertion may also influence the risk of infection associated with PACs. Two studies suggest that PACs inserted into jugular veins have a higher rate of infection compared with those inserted into subclavian veins;[36, 39] three other studies found no difference in infection rates associated with the two insertion sites.[37 38 40]

Pressure monitoring systems. Pressure monitoring systems used in conjunction with arterial catheters have been associated with both epidemic and endemic nosocomial BSIs.[41 42] The first outbreak of infections due to contamination of pressure monitoring systems was reported in 1971;[43] subsequently, 26 such outbreaks have been reported.[44–48] The final common pathway for microorganisms that enter the bloodstream of patients and cause bacteremia is the fluid column in the tubing between the patient's intravascular catheter and the pressure monitoring apparatus. Microorganisms in a fluid filled system may move from the pressure monitoring apparatus to the patient or from the patient to the pressure monitoring system.[42]

The earliest outbreaks related to pressure monitoring were due to contaminated infusate[43] or failure to sterilize the fluid pathway in reusable transducers, particularly the chamber domes.[49, 50] Because of the difficulties in sterilizing reusable transducers, sterile disposable plastic chamber domes were developed. These domes have a plastic membrane that makes contact with the sensor diaphragm on the head of the transducer and isolates the sterile fluid pathway from the transducer. However, systems containing these disposable domes have also been associated with outbreaks.[45 46 51 52] While resterilization of disposable domes may damage the membrane and permit ingress of microorganisms into the sterile fluid pathway,[53] in most outbreaks the membranes in the disposable domes

remained intact.[46, 51] A study in 1979 showed that fluid used to fill the space between the transducer head and the membrane of the disposable dome frequently contaminated the hands of the operator and that the system was inoculated by touch contamination during the subsequent assembly of the pressure monitoring system.[52] This mode of contamination is most likely to occur when glucose solutions are used between the transducer head and the chamber dome membrane and when transducers are not effectively decontaminated between uses.[54] Most outbreaks that have occurred since the introduction of the disposable chamber dome have been due to this type of contamination.[54]

Other mechanisms by which pressure monitoring systems have been contaminated include contamination of infusate,[41] in-use contamination of the system by nonsterile calibrating devices,[55] contamination of the system by ice used to chill syringes,[56] introduction of microorganisms into the system by contaminated disinfectant[49] and in-use contamination of the system related to blind, stagnant columns of fluid between the transducer and infusion system.[42] The importance of the latter mechanism in contamination was shown by a substantial drop in contamination of the system after introduction of a continuous flush device that eliminated the stagnant column of fluid.[57]

To date, no outbreaks have been reported with the use of disposable pressure transducers. A prospective study of disposable transducers has shown a very low rate of associated infection (one case of bacteremia in 157 courses of pressure monitoring).[58] This study also showed that disposable transducers can be safely used for 4 days.[58] Disposable transducers were used as a control measure in one reported outbreak caused by contaminated reusable transducers.[45]

Peripherally Inserted CVCs

Peripherally inserted CVCs (PICCs) are inserted into the right atrium by way of the cephalic and basilar veins of the antecubital space and provide an alternative to subclavian or jugular vein catheterization and, because they do not require surgical insertion, cost much less to insert than tunneled subclavian catheters or subcutaneous ports. PICCs have been used for a variety of purposes, including total parenteral nutrition (TPN) administration, and their use appears to be associated with a rate of infection similar to that reported with other percutaneously inserted CVCs.[59] Further studies are

---

[1] 1Use of trade names is for identification only and does not imply endorsement by the U.S. Public Health Service or the U.S. Department of Health and Human Services.

needed to adequately determine how long PICCs can safely be left in place [59] [60] and to determine the epidemiology and microbiology of associated infections.

Devices Used for Long-Term Vascular Access

Tunneled central venous catheters. Surgically implanted right atrial catheters, including Hickmans, Broviacs, Groshongs, and Quintons, are commonly used to provide vascular access to patients requiring prolonged intravenous therapy (e.g., chemotherapy or home-infusion therapy, hemodialysis). In contrast to percutaneously inserted (nontunneled) CVCs, these catheters have a tunneled portion exiting the skin and a Dacron cuff just inside the exit site. The cuff inhibits migration of organisms into the catheter tract by stimulating growth of the surrounding tissue, thus sealing the catheter tract and providing a natural anchor for the catheter. In general, the rates of infections reported with the use of tunneled catheters have been significantly lower than those reported with the use of nontunneled CVCs;[61–69] however, two recent studies, one randomized, found no significant difference in the rates of infection among tunneled and nontunneled catheters.[59] [70]

Totally implantable intravascular devices (TIDs). TIDs are also tunneled beneath the skin, but have a subcutaneous port or reservoir with a self-sealing septum that is accessed by needle puncture through intact skin. TIDs offer the advantage of improved patient image and obviate the need for routine catheter-site care. Among devices used for long-term vascular access, TIDs have the lowest reported rates of catheter-related BSI,[71–81] possibly because they are located beneath the skin with no orifice for ingress of microorganisms.

Recently, several investigators have attempted to compare the infectious morbidity associated with TIDs and other tunneled catheters. In one randomized study, TIDs and Hickman catheters had comparable rates of infection.[78] In another randomized study, TIDs had lower rates of infection compared with other tunneled catheters.[79] Groeger et al. conducted one of the largest comparisons of the infectious complications associated with long-term vascular access devices to date. In this prospective examination of 1431 devices in patients with cancer, TIDs (0.21 infections per 1,000 device-days) had a significantly lower rate of infectious complications compared with other tunneled catheters (2.77 infections

per 1,000 device days, p≤0.001).[80] However, the devices in Groeger's study were not randomly assigned, thus the differences observed may be due to factors other than those inherent to the devices. Existing data suggest that either of the indwelling devices can be safely used with a low risk of infection. The selection of a given device depends on the intended use, patient population, and patient/practitioner preference.

III. Microbiology

Over the past two decades, there has been a marked change in the distribution of pathogens reported to cause nosocomial BSIs.[7] [82] [83] Since the mid-1980's, an increasing proportion of nosocomial BSIs reported to NNIS have been due to gram-positive, rather than gram-negative, species. Moreover, a major portion of the overall increase in nosocomial BSIs reported to NNIS during the past decade was due to significant increases in four pathogens: coagulase-negative staphylococci (CoNS), *Candida spp.*, enterococci, and *Staphyloccocus aureus*. The distribution of these pathogens varied by hospital size and affiliation (i.e., teaching, nonteaching).[7]

CoNS, particularly *S. epidermidis*, have become the most frequently isolated pathogens in CRIs and accounted for an estimated 28% of all nosocomial BSIs reported to NNIS during 1986–89.[7] [84] The emergence of CoNS as the primary pathogen causing CRIs can be attributed to several factors: (1) increased use of prosthetic/indwelling devices (e.g., intravascular catheters);[85] (2) improved survival of low birthweight neonates and increased use of intralipids in these patients;[86] and (3) recognition of CoNS as true nosocomial pathogens rather than harmless commensals.[7] The prevalence of these pathogens also shows that the hands of healthcare workers (HCWs) and the flora of patients' skin are likely the predominant sources of pathogens for most CRIs.

Prior to 1986, *S. aureus* was the most frequently reported pathogen causing nosocomial BSIs.[84] Now, *S. aureus* accounts for an estimated 16% of reported nosocomial BSIs.[87] *S. aureus* BSIs may be complicated by metastatic foci of infection (e.g., vertebral osteomyelitis) and endocarditis.[88–90]

Enterococci, another emerging nosocomial bloodstream pathogen, accounted for 8% of nosocomial BSIs reported to NNIS during 1986–1989.[84] More alarming, has been the emergence of vancomycin-resistant enterococci (VRE). During 1989–1993, 3.8% of the blood isolates from BSIs reported to NNIS were vancomycin resistant.

Although data were not available to adequately assess the attributable mortality of either the BSI or the antimicrobial resistance of the isolate, mortality was significantly higher among patients whose isolates were vancomycin resistant (36.6%) than among those whose isolates were vancomycin susceptible (16.4%).[91] Risk factors associated with VRE BSIs include receipt of antimicrobials (including vancomycin), gastrointestinal colonization with VRE, underlying disease severity (e.g., in oncology or transplant patients), abdominal or cardiac surgical procedures, use of indwelling devices, and prolonged hospital stay.[92–99] Although enterococcal BSIs may arise from the patients' endogenous flora, nosocomial transmission of VRE via the hands of HCWs,[93] patient-care equipment,[100] and contaminated environmental surfaces [92] [93] has also been suggested by the findings of recent outbreak investigations. The emergence of enterococci as significant nosocomial bloodstream pathogens is likely due, in part, to the increased use of invasive devices and the injudicious use of broad-spectrum antimicrobials for treatment and prophylaxis of infections.[101–105]

Fungal pathogens represent an increasing proportion of nosocomial BSIs. During 1980–1990, NNIS hospitals reported a nearly fivefold increase in the rate of nosocomial fungal BSIs (1.0 to 4.9/10,000 discharges) and a nearly twofold increase in the proportion of BSIs due to fungal pathogens (5.4 to 9.9%).[106] Such increases were detected for hospitals of all sizes and affiliations and on all major hospital services. *Candida spp.*, particularly *C. albicans*, accounted for >75% of all nosocomial fungal infections reported to NNIS during this period. Candidemia has traditionally been thought to arise from the endogenous flora of colonized patients,[107–109] but recent epidemiologic studies, assisted by the use of molecular typing, show that exogenous infection due to administration of contaminated fluids,[110] [111] use of contaminated equipment,[112] cross-infection,[113–117] and the colonized hands of HCWs [118–122] are also important contributors to candidemia among hospitalized patients.

Although less commonly implicated than either gram-positive bacterial or fungal species as a cause of BSI, gram-negative microorganisms account for the majority of CRIs associated with the use of arterial catheters. Moreover, it has been suggested that clusters of infections caused by certain gram-negative species, such as *Enterobacter*

spp., Acinetobacter spp., S. marcescens or non-aeruginosa pseudomonads, should automatically raise suspicion of a common source, such as a contaminated pressure monitoring device. The predominance of gram-negative microorganisms in infections associated with pressure monitoring devices may be due to concomitant receipt of broad-spectrum antimicrobials by patients undergoing hemodynamic monitoring.

IV. Pathogenesis

The pathogenesis of CRIs is multifactorial and complex (Figure 1), but available scientific data show most CRIs appear to result from migration of skin organisms at the insertion site into the cutaneous catheter tract with eventual colonization of the catheter tip.[123–126] However, there is a smaller, but growing, body of data to suggest that hub contamination can be an important contributor to intraluminal colonization of catheters, particularly long-term catheters.[127–130]

The relative importance of these two mechanisms of catheter contamination is the source of continuing debate. Recent findings suggest that duration of catheterization influences which of the two mechanisms predominates. Using electron microscopy, Raad demonstrated that hub contamination was the more likely mechanism of infection for long-term catheters (i.e., in place >30 days), while skin contamination was the more likely mechanism for short-term catheters (i.e., <10 days).[130] Although much less common than either of these two mechanisms, hematogenous seeding of the catheter tip from a distant focus of infection or administration of contaminated infusate may also cause CRIs.[128 131–134]

Two other important pathogenic determinants of CRI are (1) the material of which the device is made, and (2) the intrinsic properties of the infecting organism. In vitro studies show that catheters made of polyvinyl chloride or polyethylene appear to be less resistant to the adherence of microorganisms than are newer catheters made of Teflon, silicone elastomer, or polyurethane.[135–137] Some catheter materials also have surface irregularities that may further enhance the microbial adherence of certain species (e.g., CoNS, *Acinetobacter calcoaceticus*, and *Pseudomonas aeruginosa*).[138 139] Thus, catheters made of certain materials may be more prone to microbial colonization and subsequent infection. Additionally, certain catheter materials are more thrombogenic than others, a characteristic that also may predispose

to catheter colonization and catheter-related infection.[140]

The adherence properties of a given microorganism are also important in the pathogenesis of CRI. For example, *S. aureus* can adhere to host proteins (e.g., fibronectin) commonly present on catheters,[141 142] and CoNS, the most frequent etiologic agents in CRIs, adhere to polymer surfaces more readily than do other common nosocomial pathogens such as *E. coli* or *S. aureus.*[143] Additionally, certain strains of CoNS produce an extracellular polysaccharide often referred to as ''slime.'' In the presence of catheters, this slime potentiates the pathogenicity of CoNS by allowing them to withstand host defense mechanisms [144 145] (e.g., acting as a barrier to engulfment and killing by polymorphonuclear leukocytes) or by making them less susceptible to antimicrobial agents [146] (e.g., forming a matrix that binds antimicrobials before their contact with the organism cell wall). More recent studies suggest that certain *Candida spp.*, in the presence of glucose-containing fluids, may produce ''slime'' similar to that of their bacterial counterparts, potentially explaining the increased proportion of BSIs due to fungal pathogens among patients receiving parenteral nutrition fluids.[147]

V. Definitions and Diagnosis of Catheter-Related Infections

Establishing a clinical diagnosis of CRI, especially catheter-related BSI, is often difficult. Diagnosis is typically based on clinical and/or laboratory criteria, with each having significant diagnostic limitations. The introduction of semiquantitative methods for culturing catheters has greatly enhanced our ability to diagnose CRIs. Both semiquantitative and quantitative methods have greater specificity in identifying CRI than do traditional broth cultures, where a clinically insignificant inocula of microorganisms can result in a positive catheter culture.[31 148]

However, interpretation of the results of these culture methods may vary depending on the type and location of the catheter and the culture methodology used. The use of varying definitions in studies of CRI have made it difficult to compare existing studies of these infections.

The predictive values of semiquantitative and quantitative methods may vary, depending on the source of catheter colonization.[130] For example, if the skin is the primary source of catheter colonization, methods that culture the external surface of the catheter may be preferable. Conversely, if hub contamination is the primary mechanism for catheter colonization,

methods that culture both the external and internal surfaces may have greater yield.[130] As the use of antimicrobial-coated catheters becomes more prevalent, existing definitions of catheter colonization and CRI may need to be modified.

Infections Associated with Short-Term Catheters

The most widely used laboratory technique for diagnosis of CRI is the roll-plate method described by Maki et al.[148] This method cultures a segment of the catheter after it has been removed from the patient by rolling the catheter segment across the surface of an agar plate and determining the number of bacterial colonies present after overnight incubation. Growth of ≥15 colony forming units (cfus) from a proximal or distal catheter segment by semiquantitative culture in the absence of accompanying signs of inflammation at the catheter site is considered indicative of catheter colonization. Growth of ≥15 cfus from a catheter by semiquantitative culture with accompanying signs of inflammation (e.g., erythema, warmth, swelling, or tenderness) at the device site is indicative of local CRI. In the absence of semiquantitative culture, CRI may be diagnosed when there is purulent drainage from the skin-catheter junction. Limitations of the roll plate method are that it requires removal of the catheter and overnight incubation before results become available.

Cooper et al. proposed direct gram-staining of catheters on removal as a rapid way to diagnose catheter infection and as a complement to semiquantitative culture.[126] However, this method appears to be considerably more time-consuming than semiquantitative culture and, thus, may be impractical for routine diagnostic use.

Acridine-orange staining of catheters has been proposed as a modification of the gram-staining technique.[149] Although similar to gram-staining, acridine-orange staining is a single-step procedure that uses a fluorescent dye to enhance detection of microorganisms in clinical specimens. This procedure avoids many of the technical shortcomings encountered with the direct gram-staining technique, but confirmatory studies documenting its quantitative test performance are needed before it can be recommended.

The most sensitive technique for diagnosis of CRI is quantitative culture. To culture a catheter quantitatively, the catheter segment is either flushed with and then immersed in broth [150] or placed in broth and sonicated; [151 152] the

broth recovered from these procedures is cultured quantitatively. Sonication releases microorganisms from both the luminal and external surfaces of the catheter and thus may have greater sensitivity for diagnosing CRIs, especially those associated with central venous and arterial catheters, than do methods that only culture the external surface of the catheter.[152]

All semiquantitative and quantitative catheter culture methods require removal of the implicated catheter, but the venous access site can be preserved by removing the catheter over a guidewire and inserting a new catheter over the guidewire. The proximal and distal segments of the catheter removed over the guidewire are cultured using the semiquantitative technique.[153] If a catheter is removed over a guidewire and has a negative culture, the catheter inserted over the guidewire may be left in place. If the catheter removed over a guidewire has a culture result suggesting colonization/infection, the second catheter should be removed, and a new catheter inserted at a new site.[59 131 153]

Quantitative blood culturing techniques have been developed for diagnosis of CR–BSI in patients where catheter removal is undesirable because of limited vascular access. These techniques rely on quantitative culture of paired blood samples, one obtained through the central catheter and the other from a peripheral venipuncture site. In most studies, a colony count from the blood obtained from the catheter that is five to tenfold greater than the colony count from the blood obtained from a peripheral vein has been predictive of CR–BSI.[154–156]

Infections Associated With Long-Term Catheters

The use of these indwelling catheters may be complicated by a variety of local infectious complications: exit-site, tunnel, or pocket infections, as defined in Table 1.[69] However, clinical diagnosis of CRI involving the intravascular portion of indwelling catheters is particularly difficult; thus, laboratory diagnosis is important. The utility of the roll-plate method for diagnosis of infection associated with long-term vascular access devices has not been evaluated, but recovery of ≥15 cfus on semiquantitative culture of a catheter segment may be diagnostic of colonization of the intravascular segment. BSI resulting from a colonized intravascular segment may also be suspected if ≥10-fold higher concentration of microorganisms on quantitative culture of blood obtained from the catheter compared with the

concentration of microorganisms in blood obtained from a peripheral venous site.[157–159]

Catheter-Related Bloodstream Infection

CR–BSI is most stringently defined as isolation of the same organism (i.e., identical species, antibiogram) from semiquantitative or quantitative cultures of both a catheter segment and the blood (preferably drawn from a peripheral vein) of a patient with accompanying clinical symptoms of BSI and no other apparent source of infection. In the absence of laboratory confirmation, defervescence after removal of an implicated catheter from a patient with BSI is also considered indirect evidence of CR–BSI.

Infusate-Related Bloodstream Infection

Since BSI may result from the administration of contaminated intravenous fluids, culturing intravenous fluids should be part of an investigation of potential sources of infection. Infusate-related BSI is usually defined as the isolation of the same organism from both infusate and separate percutaneous blood cultures, with no other identifiable source of infection.

VI. Strategies for Prevention of Catheter-Related Infections

Strict adherence to handwashing and aseptic technique remains the cornerstone of prevention of CRIs; however, other measures may confer additional protection and must be considered when formulating preventive strategies. These measures include the selection of an appropriate site of catheter insertion, selection of appropriate catheter material(s), use of barrier precautions during catheter insertion, change of catheters and administration sets at appropriate intervals, catheter-site care, and the use of filters, flush solutions, prophylactic antimicrobials, and newer intravascular devices (e.g., impregnated catheters, needleless infusion systems).

Site of Catheter Insertion

The site at which a catheter is placed may influence the subsequent risk of CRI. For peripheral venous catheters, lower extremity insertions pose a greater risk of phlebitis than do those inserted in the upper extremity, and upper extremity sites differ in their risk for phlebitis.[160–164] Peripheral venous catheters inserted into hand veins have a lower risk of phlebitis than do those inserted in upper arm or wrist veins.[6]

Among CVCs, catheters inserted into subclavian veins have a lower risk for infection than do those inserted in

either jugular or femoral veins.[31–36 39] Internal jugular insertion sites may pose a greater risk for infection because of their proximity to oropharyngeal secretions, and because catheters at internal jugular sites are difficult to immobilize. However, mechanical complications associated with insertion are less common with internal jugular vein insertion than with subclavian venous catheterization.

Type of Catheter Material

The relationship between catheter material and infectious morbidity has been largely examined by the study of peripheral venous catheters. The majority of peripheral venous catheters in the U.S. are made of Teflon or polyurethane, and these catheters appear to be associated with fewer infectious complications than are catheters made of polyvinyl chloride or polyethylene.[17 135 165] In one large, randomized prospective study of Teflon and polyurethane catheters, the two types of catheters had comparable rates of local infection, 5.4% and 6.9%, respectively,[17] but polyurethane catheters were associated with a nearly 30% lower risk of phlebitis when compared with Teflon catheters. In this trial, neither the Teflon nor polyurethane catheter was associated with BSI.[17] By contrast, polyvinyl chloride or polyethylene catheters have been associated with BSI rates ranging from 0%-5%.[166 167]

Steel needles, used as an alternative to synthetic catheters for peripheral venous access, have the same rate of infectious complications as do Teflon catheters.[168 169]

However, the use of steel needles is frequently complicated by infiltration of intravenous fluids into the subcutaneous tissues, a potentially serious complication if the infused fluid is a vesicant.[169] In view of the low rates of BSI seen with newer Teflon and polyurethane catheters, the relative risks and benefits of using steel needles must be evaluated on an individual patient basis.

Catheter material seems to also be an important determinant in the risk of infection associated with CVCs. Most CVCs used in the U.S. are made of polyurethane, polyvinyl chloride, polyethylene, or silicone. In one small, prospective trial comparing silicone with polyvinyl TPN catheters, silicone catheters had a significantly lower rate of CR–BSI than did polyvinyl chloride catheters, 0.83 and 19 per 1,000 catheter days, respectively; however, the silicone catheters were tunneled, and the polyvinyl chloride catheters were largely nontunneled. The polyvinyl

chloride catheters also were associated with a higher risk of mechanical complications (i.e., breakage, blockage, displacement, and thrombosis).[170] Because of the potential confounding caused by the different types of catheters in this comparison (i.e., tunneled vs. nontunneled), appropriate conclusions about the contribution of catheter material to CVC-related infections can not be drawn.

Barrier Precautions During Catheter Insertion

It is generally accepted that good handwashing before and attention to aseptic technique during insertion of peripheral venous catheters provide adequate protection against infection. Central venous catheterization, however, carries a significantly greater risk of infection, and the level of barrier precautions needed to prevent infection during insertion of CVCs has been a source of debate.

Until recently, it was assumed that catheters inserted in the operating room posed a lower risk of infection than did those inserted on inpatient wards or other patient-care areas. However, data from two recent prospective studies suggest that the difference in risk of infection depends largely on the magnitude of barrier protection used during catheter insertion, rather than the sterility of the surrounding environment (i.e., ward vs. operating room) [36] [171]; CVCs or PACs inserted in the operating room using submaximal barrier precautions (i.e., gloves, small fenestrated drape) were more likely to become colonized and to be associated with subsequent BSI than were those inserted on the ward or in the ICU using maximal barrier precautions (i.e., gloves, gown, large drape, masks). These data suggest that if maximal barrier precautions are used during CVC insertion, catheter contamination and subsequent CVC-related infections can be minimized, irrespective of whether the catheter is inserted in the operating room or at the patient's bedside.[171] [172]

Changing Catheters and Administration Sets

Intravenous administration set changes. The optimal interval for routinely changing intravenous administration sets used for patient care has been examined in three well-controlled studies. Data from each of these studies show that changing administration sets ≥72-hours after initiation of use is not only safe, but cost-beneficial.[173–175] However, because certain fluids (i.e., blood, blood products, TPN, and lipid emulsions) are more likely than other parenteral fluids

to support microbial growth if contaminated, [132] [176–179] more frequent tubing changes may be required when such fluids are administered.

A common component of intravenous administration sets is the stopcock. Stopcocks are used for injection of medications, administration of intravenous infusions, or collection of blood samples and, thus, represent a potential portal of entry for microorganisms into vascular catheters or intravenous fluids. Although stopcock contamination is common, ranging between 45% and 50% in most series, the relative contribution of stopcock contamination to intravascular catheter or intravenous fluid contamination is unclear. Few studies have been able to demonstrate that the organism(s) colonizing stopcocks is the same one responsible for CRI.[180] [181] Data suggest that the use of a closed-needle sampling system can significantly reduce sampling-port and intravenous fluid contamination.[182] [183]

"Piggyback" systems may be used as an alternative to stopcocks. However, they also pose a risk for contamination of the intravascular fluid if the needle entering the rubber membrane of an injection port is partially exposed to air, or comes into direct contact with the tape used to fix the needle to the port. A recently described "piggyback" system appears to prevent contamination at these sites and reduces the incidence of CR–BSI sixfold compared with conventional stopcock and "piggyback" systems.[182]

Intravenous catheter changes. Routine or scheduled change of intravascular catheters has been advocated as a method to reduce CRIs. Studies of peripheral venous catheters show that the incidences of thrombophlebitis and bacterial colonization of catheters seem to increase dramatically when catheters are left in place >72 hours.[12] [168] Both phlebitis and catheter colonization have been associated with an increased risk of CRI. Because of the increased risk of infection, as well as patient discomfort associated with phlebitis, peripheral catheter sites are commonly rotated at 48–72 hour intervals to reduce the risk of phlebitis.

In the maintenance of CVCs, decisions regarding the frequency of catheter change are substantially more complicated. Some investigators have shown duration of catheterization to be a risk factor for infection, [33] [35] [184] [185] and routine change of CVCs at specified intervals has been advocated as a measure to reduce infection. However, more recent data suggest that the daily risk of infection remains constant and show that routine changes of CVCs,

without a clinical indication, do not reduce the rate of catheter colonization or the rate of catheter-related BSI.[186, 187]

The method of replacing CVCs has also been a topic of controversy and intensive study. CVCs can be changed by placing a new catheter over a guidewire at the existing site or by inserting the new catheter at another site. Catheter replacement over a guidewire has become an accepted technique for changing a malfunctioning catheter or exchanging a PAC for a CVC when invasive monitoring is no longer needed. Catheters inserted over a guidewire are associated with less discomfort and a significantly lower rate of mechanical complications than are those percutaneously inserted at a new site.[131] [186] [188] [189] Guidewire-assisted exchange may, however, be accompanied by complications, most notably bleeding at the site, hydrothorax, and subsequent infection of the newly placed catheter.[131] [189]

Studies examining the infectious risks associated with guidewire insertions have yielded conflicting results. Three prospective studies (two randomized) have shown no significant difference in infection rates between catheters inserted percutaneously and those inserted over a guidewire.[153] [187] [190] One prospective randomized study has shown a significantly higher rate of BSIs associated with catheters changed over a guidewire compared with catheters inserted percutaneously.[186] Most investigators agree that if guidewire-assisted catheter change occurs in the setting of an CRI, the newly placed catheter should be removed (131,153,187,188).

Catheter-Site Care

Cutaneous antiseptics and antimicrobial ointments. Skin cleansing/antisepsis of the insertion site is regarded as one of the most important measures for preventing CRI, but comparative studies of cutaneous antisepsis have largely examined its efficacy in eradicating bacterial flora from the hands of hospital personnel.[191] [192] However, in one trial, the effectiveness of 2% chlorhexidine, 10% povidone-iodine, and 70% alcohol [193] as cutaneous antiseptics were compared in preventing central venous and arterial CRIs. The rate of catheter-related BSI when chlorhexidine was used for catheter site preparation was 84% lower than the rates when the other two antiseptic regimens were used; however, the 2% chlorhexidine preparation used in this trial is not currently available in the U.S. More recently, a sustained-release chlorhexidine gluconate patch (250 mu/

mg dressing) has been introduced as a dressing for catheter insertion sites. In one randomized trial of epidural catheters, the use of these patches significantly reduced the incidence of catheter colonization.[194] However, the efficacy of the chlorhexidine patch in reducing intravascular device-related infection still needs to be determined.

Tincture of iodine also has been widely used in hospitals for skin antisepsis before catheter insertion, but its efficacy in reducing catheter colonization and infection have not been thoroughly evaluated. Data derived from examining its use as an antiseptic prior to blood culturing suggest that it, like 70% alcohol and 10% povidone iodine, may be an effective cutaneous antiseptic for preparation of the skin prior to insertion of intravascular catheters.[195] However, tincture of iodine may cause skin irritation.[195]

The application of antimicrobial ointments to the catheter site at the time of catheter insertion and/or during routine dressing changes has also been used to reduce microbial contamination of catheter-insertion sites. Studies of the efficacy of this practice in preventing CRIs have yielded contradictory findings.[30 196–200] Moreover, the use of polyantibiotic ointments that are not fungicidal may significantly increase the rate of colonization of the catheter by *Candida* spp.[198 200 201]

Recently, topical mupirocin, a nonsystemic anti-staphylococcal antimicrobial with documented efficacy in reducing nasal staphylococcal spp. carriage,[202] has been used for cutaneous antisepsis in conjunction with 2.5% tincture of iodine prior to catheter insertion. Used in this way, mupirocin was reported to reduce the incidence of internal jugular catheter colonization among cardiac surgery patients. However, the utility of mupirocin in reducing the rate of colonization of peripheral or arterial catheters has not been demonstrated[203] and its use on catheter sites has not been approved. Moreover, mupirocin resistance has been reported (204–206). Controlled studies are needed to fully evaluate the effectiveness and potential adverse effects of mupirocin use for catheter-site maintenance.

Catheter-site dressing regimens. Transparent, semipermeable, polyurethane dressings have become a popular means of dressing catheter-insertion sites. These transparent dressings reliably secure the device, permit continuous visual inspection of the catheter site, permit patients to bathe and shower without saturating the dressing, and require less frequent changes than do standard gauze and tape dressings, thus saving personnel time. Nevertheless, the use of transparent dressings remains one of the most actively researched, and controversial, areas of catheter site care. Some studies suggest that their use increases both microbial colonization of the catheter site and the risk of subsequent CRI,[15 207–210] while other studies have shown no difference in catheter colonization and infection rates between the use of transparent dressings and gauze and tape dressings.[10 165 211] The potential risk of infection posed by transparent dressings appears to vary with the type of catheter (peripheral or central venous catheter) they are used to dress and, perhaps, with the season of the year.[10 15 209]

In the largest controlled trial of dressing regimens to date, Maki et al. examined the infectious morbidity associated with the use of transparent dressings on >2,000 peripheral catheters.[165] Their findings suggest that the rate of catheter colonization among catheters dressed with transparent dressings (5.7%) is comparable to that of those dressed with gauze (4.6%) and that there are no clinically important differences in either the incidences of catheter-site colonization or phlebitis between the two groups. Further, these data suggest that transparent dressings can be safely left on peripheral venous catheters for the duration of catheter insertion without increasing the risk of thrombophlebitis.[165]

Studies of the use of transparent dressings on CVCs have also yielded contradictory findings. Some investigators have found an increased risk of CRI among CVCs with a transparent dressing compared with those gauze;[209 210] others have found the risk of infection posed by these two types of dressings to be comparable.[211 212] Most of the data on the use of transparent dressings on CVCs are derived from studies of short-term nontunneled devices and little data have been published regarding the use of transparent dressings on long-term, tunneled CVCs.[213] In a metaanalysis of catheter dressing regimens, CVCs on which a transparent dressing was used had a significantly higher incidence of catheter tip colonization, but a nonsignificant increase in the incidence of CR–BSI.[214] Preliminary data suggest that newer transparent dressings that permit the escape of moisture from beneath the dressing may be associated with lower rates of skin colonization and CRI,[213 215] but the length of time that a transparent dressing can be safely left on a CVC catheter site is unknown.

Collodion has also been evaluated for use as a potential dressing for catheter sites. One small (n=34), retrospective study of its use on CVCs reported a low incidence of CRIs, despite catheters remaining in place an average of 16.5 days.[216] However, before collodion can be recommended for routine use as a catheter site dressing, randomized trials comparing collodion to existing dressings should be done.

In-Line Filters

In-line filters may reduce the incidence of infusion-related phlebitis (217–220), but there are no data to support their efficacy in preventing infections associated with intravascular devices and infusion systems. Proponents of the use of filters cite a number of potential benefits: (1) reducing the risk of infection from contaminated infusate or proximal contamination (i.e., introduced proximal to the filter); (2) reducing the risk of phlebitis in patients who require high doses of medication (e.g., antimicrobials) or in those in whom infusion-related phlebitis has already occurred; (3) removing particulate matter that may contaminate intravenous fluids;[221] and (4) filtering endotoxin produced by gram-negative organisms in contaminated infusates.[222] These theoretical advantages must be tempered by the knowledge that infusate-related BSI rarely occurs and that pre-use filtration in the pharmacy is a more practical, and less costly, way to remove particulates from infusates. Furthermore, in-line filters may become blocked, especially with certain solutions (dextran, lipids, mannitol), and consequently increase line manipulations and/or decrease the availability of administered drugs.[223] Because of these potential untoward effects, the routine use of in-line filters may increase cost, personnel time, and possible infections.[224]

Silver-Chelated Collagen Cuffs

Since 1987, a silver-chelated, collagen cuff that is attachable to percutaneously inserted CVCs has been commercially available. Similar to the cuff used on Hickman and Broviac catheters, this cuff is designed to form a mechanical barrier to skin microorganisms migrating into the cutaneous catheter tract;[201 225] the silver provides an additional antimicrobial barrier.[201 225] Two randomized controlled trials examining the efficacy of silver-chelated collagen cuffs have been published. In the first trial, cuffed CVCs were associated with a threefold lower risk of catheter colonization and a nearly fourfold lower risk of CR–BSI compared with traditional noncuffed CVCs.[225] In the second trial, a 78% reduction in

catheter colonization and a 100% reduction in CR–BSI were observed with these devices.[201] The relative contribution of the cuff versus the antimicrobial properties of the silver preventing CRI is uncertain. No controlled trials examining the efficacy of cuffs without antiseptic or antimicrobial coating have been published.

The protective effect of these cuffed CVCs appears to be immediate and exceeds that seen with the use of antimicrobial ointment alone.[201] However, cuffs appear to be most beneficial with catheters left in place for >4 days.[225] Studies on the efficacy of these cuffs in preventing infection with longer-term CVCs (i.e., >20 days) have not been published.

Antimicrobial-Impregnated (Coated) Catheters

In animal models, antimicrobial or antiseptic impregnation of catheters appears to reduce bacterial adherence and biofilm formation,[226 227] but the utility of these impregnated catheters in clinical settings has only recently been evaluated. Kamal et al. conducted a large, randomized, prospective trial among SICU patients to evaluate a CVC bonded with cefazolin for the entire length of its external and luminal surfaces.[228] The authors found a sevenfold reduction in the incidence of catheter colonization (2% vs 14%), but no difference in catheter-site inflammation (i.e., culture-negative inflammation of the insertion site). No bacteremias occurred in either group. The authors suggest that antimicrobial coating of the luminal surfaces of catheters may be particularly beneficial in reducing the risk of infection resulting from hub contamination.

Data supporting the utility of antimicrobial coating for peripheral catheters are much less conclusive. Kamal et al. also studied a small number of peripheral arterial catheters as part of their evaluation of the cefazolin-impregnated catheter.[228] Although impregnated peripheral arterial catheters had a fivefold lower incidence of CRI compared with noncoated catheters (3% vs 15%), this difference was not statistically significant. The lack of demonstrable efficacy of antimicrobial coating of peripheral arterial catheters in reducing CRI may be due, in part, to the inherently low incidence of CRI associated with the use of peripheral arterial catheters.

Of the studies reported to date, antimicrobial-coated catheters do not appear to pose any greater risk of adverse effects than do noncoated catheters, but additional controlled trials need to be done to fully evaluate their efficacy, determine the appropriate situations for their use, and assess the risk of emergence of resistant bloodstream pathogens.

Intravenous Therapy Personnel

Because insertion and maintenance of intravascular catheters by inexperienced staff may increase the risk of catheter colonization [153] and CR–BSI, many institutions have established infusion therapy teams. Available data suggest that trained personnel designated with the responsibility for insertion and maintenance of intravascular devices provide a service that effectively reduces CRIs and overall costs.[229–231]

Prophylactic Antimicrobials

Prophylactic administration of antimicrobials has been used to reduce the incidence of CR–BSIs, but scientific studies on the efficacy of this practice are inconclusive. Two published studies, one randomized [232] and one nonrandomized,[233] suggest that antimicrobials administered systemically at the time of (or immediately after) insertion of a CVC may reduce the incidence of CR–BSI. Two randomized trials of systemically administered antibiotics demonstrated no benefit of such prophylaxis.[234 235] One randomized controlled trial showed a significant protective effect of a heparin-vancomycin flush solution used daily in immunocompromised patients with tunneled CVCs.[236] Two other randomized controlled trials have examined the effect of continuous low dose ($25\mu g$) vancomycin, added to TPN fluids, in reducing the incidence of CoNS BSI in low birthweight infants.[237 238] In one of these trials, the incidence of CoNS BSI decreased from 34% to 1.4% (P<0.001) among neonates weighing <1500 gm.[237] However, 4/71 (5.6%) treated neonates developed a BSI due to gram-positive cocci after vancomycin prophylaxis was completed. The other trial studied neonates weighing <1000 gm and found that the use of vancomycin was associated with a significantly lower incidence (0% vs 15%) of CoNS CR–BSI.[238] Although prophylactic administration of vancomycin decreased the incidence of CoNS BSI, it did not decrease overall mortality among low birth weight infants in either study. Further studies are needed to assess the additional benefit afforded by prophylactic antimicrobials in reducing CRIs when standard infection control measures are adhered to and to assess the concern that such prophylaxis may select for resistant microorganisms, particularly those resistant to vancomycin.

Flush Solutions, Anticoagulants, and Other Intravenous Additives

Flush solutions are designed to prevent thrombosis, rather than infection, but thrombi and fibrin deposits on catheters may serve as a nidus for microbial colonization of the intravascular devices. Furthermore, catheter thrombosis appears to be one of the most important factors associated with infection of long-term catheters.[69 239] Thus, the use of anticoagulants (e.g., heparin) or thrombolytic agents may have a role in the prevention of CR–BSI. However, several recent studies suggest that 0.9% saline is as effective as heparin in maintaining catheter patency and reducing phlebitis among peripheral catheters.[137 240 241] Furthermore, recent in vitro studies suggest that the growth of CoNS on catheters may be enhanced in the presence of heparin. In contrast, the growth of CoNS on catheters can be inhibited by edetic acid (EDTA),[242] suggesting that EDTA, rather than heparin, may decrease the incidence of CoNS CR–BSIs. Also, the routine use of heparin to maintain catheter patency, even at doses as low as 250–500 units/day, has been associated with thrombocytopenia and thromboembolic and hemorrhagic complications.[243–246] Clinical trials are needed to further assess the relative efficacy, risks, and benefits of the routine use of various anticoagulants (e.g., EDTA) in preventing CRI.

The risk of phlebitis associated with the infusion of certain fluids (e.g., potassium chloride,[247] lidocaine,[247 248] antimicrobials,[247] also may be reduced by the use of certain intravenous additives, such as hydrocortisone.[247] Bassan et al. in a prospective, controlled trial of patients being evaluated for possible myocardial infarction found that heparin and/or hydrocortisone significantly reduced the incidence of phlebitis in veins infused with lidocaine.[248] In other trials, topical application of venodialators such as glycerol trinitate,[249 250] or anti-inflammatory agents such as cortisone near the catheter site,[251] has effectively reduced the incidence of infusion-related thrombophlebitis and increased the life span of the catheters.[251 252] Larger, controlled trials are needed to assess the advisability of the routine use of these agents to reduce phlebitis.

Needleless Intravascular Devices

Attempts to reduce the incidence of sharps injuries and the resultant risk of transmission of bloodborne infections to

HCWs have led to the design and introduction of needleless intravenous systems. However, there are limited data by which to assess the potential risk of contamination of the catheter and infusate and subsequent CRI that may be associated with the use of these devices. In one trial where conventional and needleless heparin-lock systems were compared, the rates of infection were comparable.[253] However, in another investigation, the combined use of a needleless infusion system and TPN was associated with an increased rate of BSIs among patients receiving home infusion therapy.[254] As the use of these systems becomes more widespread, the potential infectious risks associated with their use can be more fully evaluated.

Multidose Parenteral Medication Vials (MDVs)

Parenteral medications are commonly dispensed in MDVs that may be used for prolonged periods for one or more patients. Although the overall risk of extrinsic contamination of MDVs appears to be small, an estimated 0.5 per 1,000 vials,[255] the consequences of contamination may be serious. Contamination of MDVs due to breaks in aseptic technique have resulted in several nosocomial outbreaks. The implicated vehicles in these outbreaks have been lipids infused intravenously from multidose containers[177] and medications used for intra-articular injections.[256 257] However, when bacteria or yeasts were inoculated into some commonly used medications, such as heparin, potassium chloride, procainamide, methohexital, succinylcholine chloride, and sodium thiopental, and left at room temperature, no microorganisms could be cultured from these medications after 96 hours, with rare exceptions, irrespective of whether they contained a preservative.[258] Microorganisms could proliferate in lidocaine and insulin only if the inocula were prepared in peptone water (with one exception), which allowed for transfer of nutrients to the vials. Even under these conditions, when vials were kept at 4°C (the recommended storage temperature), microorganisms did not proliferate in the insulin. There is one report of hepatitis B virus transmission related to the use of a contaminated vial of bupivacaine in a hemodialysis unit.[259]

VII. Intravascular Device-Related Infections Associated With Total Parenteral Nutrition

Catheter-related BSI remains one of the most important complications of TPN therapy and reported rates of infection during TPN vary widely depending on the population studied and the definitions used. Because TPN solutions commonly contain dextrose, amino acids, and/or lipid emulsions, they are more likely than conventional intravenous fluids to support microbial growth if contaminated.[177 179 260–263] Lipid emulsions are particularly suited for the growth of specific bacteria and yeasts,[176 177] with microbial growth occurring as early as 6 hours after inoculation of a lipid emulsion and reaching clinically significant levels (>10^6 CFU/ml) within 24 hours.[178] Newer combined TPN solutions (e.g., 3-in-1 system) which use glucose, amino acids, lipid emulsion, and additives in one multiliter administration bag, may increase the risk of infection associated with TPN, but data on which to assess this risk are not available.

Although TPN solutions are particularly suited for microbial growth, most infections that occur during the administration of TPN result from contamination of the catheter. TPN-related CRI result much less commonly from infusion of contaminated fluids or from hematogenous seeding of the catheter.

The microbiology of TPN-related CR–BSIs is similar to that of other CR–BSIs, with gram-positive species, particularly CoNS or *S. aureus*, being the predominant pathogens. However, the proportion of BSIs due to fungal pathogens, particularly *Candida* spp., are significantly greater in patients receiving TPN.[106]

Risk Factors

A number of factors have been associated with the development of CRI during TPN therapy, including catheter-site colonization,[123 125 155] method and site of catheter insertion, the experience of the personnel inserting the catheter,[153] the use of the TPN line for purposes other than administration of parenteral nutrition fluids,[264] breaks in the protocol for aseptic maintenance of the infusion systems,[167 223 264 265] and the use of triple-lumen catheters.[24 25 27 28]

Surveillance and Diagnosis

Surveillance for CRI during TPN administration should be the same as during the administration of other types of infusion therapy. Although culturing the skin adjacent to the catheter insertion site may help predict BSI in patients who are receiving TPN,[123 125 155] routine microbiologic surveillance can not be advocated. As with other suspected CRIs, semiquantitative and quantitative catheter cultures may also be useful for the diagnosis of TPN-related CRIs. Vanhuynegem et al. evaluated the efficacy of semiquantitative cultures of blood drawn through in place TPN catheters in febrile patients for diagnosing CR–BSI.[266] Comparing their methodology to the semiquantitative culture technique of Maki, they found that such cultures had a positive predictive value of 60%, and a negative predictive value of 100%. Moreover, using this technique, they were able to prevent unnecessary removal of 87% of the catheters in which infection was suspected.

Strategies for Prevention

The strategies previously outlined for the prevention of CRIs are also effective in reducing the risk of infections associated with TPN, and rigorous aseptic nursing care has been shown to greatly reduce the incidence for TPN-related infection.[265 267 268] Nevertheless, a number of supplemental preventive measures that have been proposed to reduce the risk for TPN-related CRIs bear discussion, including special precautions for infusate preparation, cutaneous antisepsis, and catheter selection and care.

Infusate preparation. Since TPN solutions are prone to microbial growth if contaminated, strict attention must be given to asepsis during the compounding of TPN solutions. Although controlled trials have not been done, centralized preparation of TPN solutions in hospital pharmacies, using a laminar flow hood, has generally been regarded as the safest method of preparation.

Cutaneous antisepsis. Findings on the efficacy of various antiseptic skin preparations on decreasing the incidence of CRI during TPN suggest that tincture of iodine and chlorhexidine in ethyl alcohol are superior to povidone-iodine as a skin antiseptic during TPN catheter care.[269] Furthermore, in one prospective randomized study, the application of povidone-iodine ointment to the insertion sites of subclavian catheters used for TPN was not associated with a decrease in CRIs when compared with catheters on which povidone-iodine was not used.[268]

The application of organic solvents, such as acetone or ether, to ''defat'' (remove skin lipids) the skin prior to catheter insertion and during routine dressing changes has been a standard component of many hyperalimentation protocols. However, these agents appear neither to confer additional protection against skin colonization nor significantly decrease the incidence of CRI. Moreover, their use can greatly increase local inflammation and patient discomfort.[270]

Selection of catheter. Tunnelling of TPN catheters has been proposed for three reasons: (1) to prevent dislodgement of the catheter; (2) to reduce the incidence of CR–BSI by increasing the distance between the sites where the catheter exits the skin and where it enters the subclavian vein; and (3) to protect the catheter from potentially contaminated sites such as tracheostomies. However, few prospective randomized studies have been done to evaluate the efficacy of this practice. When Koehane et al. assessed the risk of BSI among patients with short-term, noncuffed, tunneled and nontunneled TPN catheters, they demonstrated a reduction in the incidence of CR–BSI among tunneled catheters as compared with nontunneled catheters.[267] However, this reduction was greatest when a designated nutrition nurse was used to maintain the catheter; after improved adherence to the infection control protocol, short-term, noncuffed, tunneled and nontunneled catheters were associated with a similar rate of BSI. The only other controlled trial of short-term, noncuffed, tunneled and nontunneled catheters similarly failed to demonstrate a beneficial effect of tunnelling after rigorous attention to infection control,[127] suggesting that if strict infection control practices are adhered to, short-term, noncuffed, tunneled and nontunneled TPN catheters have a similar risk of infection.

Catheter-site dressings. The use of occlusive dressings on catheters used for TPN has been a continuing source of debate. Two controlled studies suggest that, with adherence to strict infection control protocols, semipermeable, transparent dressings are a safe, cost-effective alternative to gauze and tape for dressing TPN catheter-insertion sites.[212 268] Moreover, data suggest that transparent dressings used on TPN catheter sites can be safely changed at 7-day intervals.[212 268 271]

Catheter changes. Prospective, randomized trials examining the frequency of TPN catheter changes have not been published. However, data from a study in 1974 suggest that the rate of infection (6.2%) for TPN catheters in place for >30 days is similar to the rate of infection (7%) for all catheters.[265]

Specialized personnel. Many institutions have protocols and a nutritional support team for insertion and maintenance of catheters used for TPN. As with vascular devices used for other purposes, the use of specially trained personnel to insert and maintain the catheters appears to reduce the rate of infection in patients receiving TPN.[230, 231, 267]

VIII. Intravascular Device-Related Infections Associated With Hemodialysis Catheters

Epidemiology

Each year approximately 150,000 patients undergo maintenance hemodialysis for chronic renal failure. Since 1979, when the Uldall subclavian catheter was introduced, CVCs have gained popularity as a convenient, rapid way of establishing temporary vascular hemodialysis access until placement or maturation of a permanent arteriovenous fistula or permanent access for patients without alternative vascular access.[272] In 1990, an estimated 73% of centers participating in the National Surveillance System for Hemodialysis Associated Diseases had ≥1 patients in whom CVCs were used for permanent vascular access.[273] However, only a limited number of controlled trials examining the infectious risk associated with the use of CVCs for hemodialysis have been published; most data are derived from small studies at individual institutions.

Subclavian hemodialysis catheters have been associated with a rate of BSI that exceeds that reported for virtually all other subclavian catheters[274–283] or for alternative forms of hemodialysis vascular access[275 284] and their use may be complicated by bacterial endocarditis, septic pulmonary emboli,[274 275 282 284] and/or thrombosis (e.g., venous thrombosis, catheter occlusion). The factors contributing to the increased rate of infection experienced with CVCs used for hemodialysis have not been fully elucidated,[277 278] but manipulations and dressing changes of dialysis catheters by inadequately trained personnel,[285] duration of catheterization and mean number of hemodialysis runs,[277] and cutdown insertion of the catheter[286] may increase the risk of CRI among hemodialysis patients.

More recently, jugular vein catheters have been used for hemodialysis access because descriptive studies indicate that they are associated with fewer mechanical complications than subclavian catheters, including subclavian thrombosis, stenosis, and perforation.[287–294] These double-lumen, Dacron-cuffed, silicone CVCs have been used for exclusive, or prolonged, vascular access in chronic hemodialysis patients[286 295] and appear to have a longer median use-life and fewer insertion complications than do either of their single-lumened Teflon or polyurethane counterparts.[280 295 296] Moss et al. recently reviewed the 4-year experience with double-lumen, cuffed, silicone catheters at their institution. All catheters (n=168) had been placed for long-term use (≥1 month) and were the sole vascular access for hemodialysis.[286] The median life span for these catheters was 18.5 months, with 12- and 24-month catheter survival being 65% and 30%, respectively. As with subclavian hemodialysis catheters, thrombosis (catheter and vein) and infection were the most frequent catheter complications. BSI occurred in 16/131 (12%) patients and exit-site infections in 28/131 (21%); diabetics (33%) were significantly more likely to develop exit-site infections than were nondiabetics (11%). Based on the duration of catheterization, the authors determined the following rates of CRIs associated with the use of double-lumen CVCs: 0.25 BSIs per patient-year, 0.36 exit-site infections per patient-year (nondiabetics), and 0.87 exit-site infections per patient-year (diabetics). The BSI rates reported in this review were comparable to those reported for more conventional forms of hemodialysis vascular access (0.09–0.20 BSIs per patient-year).[284 297–299]

Two studies have examined the potential impact of tunneled hemodialysis catheters on the risk of subsequent CRI. In a nonrandomized study, Hickman catheters used for prolonged hemodialysis access was associated with a significantly lower rate of BSI (0.08 BSIs per 100 catheter-days) than were nontunneled hemodialysis catheter.[300] Schwab et al. prospectively examined the use of cuffed, tunneled, double-lumen jugular venous catheters for prolonged hemodialysis access. Compared with percutaneously inserted, noncuffed subclavian dialysis catheters, double-lumen jugular venous catheters had a longer live span, a lower (1.3% vs 3.6%) incidence of associated BSIs, but a significantly higher incidence of exit-site infection (29% vs 9%).[295]

Hemodialysis catheters may become contaminated by a variety of proposed mechanisms: (1) penetration of organisms from the skin due to the pulsatile action of the dialysis pump; (2) manipulation of catheter connections by medical personnel with contaminated hands; (3) leakage of contaminated hemodialysis fluid into the blood compartment; or (4) administration of contaminated blood or other solutions through the catheter during the dialysis session.

Microbiology

CR–BSIs in hemodialysis patients, as in other patient populations, are most frequently caused by S. epidermidis.[274–276 281–283 285] However, because of their high rates of

colonization with *S. aureus*,[301] hemodialysis patients have a greater proportion of CR–BSIs due to *S. aureus*[284] than among other patient populations.

Strategies for Prevention of Hemodialysis Catheter-Related Infections

Strategies for the prevention of infections associated with the use of hemodialysis catheters have not been as rigorously examined as those proposed for the prevention of infections associated with CVCs used for other purposes. Although there are limited data on infectious complications in hemodialysis settings associated with various types of catheters, frequency of catheter change, cutaneous antisepsis, and prophylactic administration of antimicrobials, no studies examining catheter-site dressing regimens, or the utility of newer devices, such as antimicrobial-impregnated hemodialysis catheters have been published.

Cutaneous antisepsis. In some series, as many as 50 to 62% of hemodialysis patients have been found to be carriers of S. aureus.[301–304] Therefore, skin antisepsis is a crucial component for the prevention of hemodialysis catheter-associated infections. In one randomized, controlled study of 129 subclavian dialysis catheters, the routine application of povidone-iodine ointment to catheter-insertion sites was more effective than plain gauze in reducing the incidence of exit-site infections (5% vs 18%), catheter-tip colonization (17% vs 36%), and BSIs (2% vs 17%);[304] duration of catheterization was comparable for treated (mean, 38.6 days) and nontreated (mean, 36.2 days) catheters, each ranging from 2–210 days. The beneficial effect of povidone-iodine ointment was most evident among patients with S. aureus nasal carriage where its use reduced the incidences of BSI and exit-site infection by 100% and catheter-tip colonization by 71%. No adverse effects were detected with the routine application of povidone-iodine ointment to subclavian dialysis catheter-insertion sites.

Catheter changes. Since attainment and preservation of vascular access in patients with chronic renal failure are often difficult, the frequency of catheter change and the role of guidewire catheter exchange are of utmost importance. However, to date, there are limited data on which to base recommendations for either of these issues in hemodialysis patients. One prospective, randomized trial of subclavian dialysis catheters using guidewire exchange suggested that the rate of BSIs was comparable when catheters were changed weekly or when clinically indicated.[305] One recent study examined the role of guidewire exchange in the treatment of infected jugular vein hemodialysis catheters. In this study, a 92% one-year catheter survival was observed with the combined use of guidewire exchange and administration of antimicrobials 48 hours before and 2 weeks after guidewire exchange, when frank pus was not present at the exit site.[306] These findings, however, are contrary to a large body of data suggesting that guidewire exchange should not be done in the setting of documented CRI.[59 131 153 307 308]

Prophylactic antimicrobials. Hemodialysis patients receiving antistaphylococcal antimicrobials at the time of catheter placement have been shown to have a lower incidence of CRI.[274 276 277 309] However, the role of prophylactic antimicrobials has not been directly studied.

Whether hemodialysis catheters can be treated in the same way as CVCs used for other purposes is unclear. Prospective, controlled trials of hemodialysis catheters are needed to determine the epidemiology of CRIs associated with their use and to evaluate the role of preventive role of different types of catheter materials, appropriate insertion sites, intervals for catheter change, guidewire exchange, catheter-site dressing regimens, and the use of newer modalities (e.g., such as antimicrobial-impregnated hemodialysis catheters).

IX. Intravascular Device-Related Infections in Pediatric Patients

This section addresses some of the specific issues relevant to intravascular access and intravascular device-related infections among the pediatric population. However, the epidemiology of intravascular-device related infections in pediatric patients is less well-described than that in adults, and there are limitations to the existing data. First, few controlled trials of intravascular devices in children have been reported; most published data are derived from uncontrolled retrospective or prospective studies. Second, pediatric data that are available were derived, largely, from studies in neonatal (NICU) or pediatric intensive care units (PICU) where rates of infection are usually higher than on general pediatric wards. Finally, semiquantitative culture methods have, in large part, not been used in the studies of CRIs in children because such cultures require catheter removal.

Microbiology

As in adults, most CR–BSIs in children are caused by staphylococcal spp., with *S. epidermidis* being the predominant species.[310 311] Other species of gram-positive cocci and fungi are the next most frequently isolated pathogens, with Malassezia furfur being an especially common pathogen in neonates receiving intravenous intralipids.[311–319]

Bertone et al. performed quantitative skin cultures on 50 neonates to determine the microbial flora present at commonly used catheter-insertion sites.[320] Only 33 neonates had an intravascular device in place at the time of culturing; 25 had peripheral venous catheters and eight had CVCs. The highest mean colony counts were found at jugular sites (2.7×10^4 cfus/10cm^2) and the lowest at subclavian sites (5.2×10^3 cfus/10-cm^2). However, femoral and jugular sites had similar mean colony counts as did subclavian and umbilical sites. Although CoNS was the pathogen most frequently cultured from all body sites, other microbial species (e.g., aerobic gram-negative bacilli, yeast, and Enterococcus spp.) were more commonly cultured from umbilical and femoral sites.[320]

Epidemiology

The majority of nosocomial BSIs in children are also related to the use of an intravascular device. During 1985–1990, children's hospitals participating in NNIS and conducting ICU surveillance reported significantly higher rates of BSI among PICU patients with CVCs (11.4 BSIs per 1,000 central-catheter days) compared with those without CVCs (0.4 BSIs per 1,000 noncentral-catheter days).[8] Participating Level III NICUs reported a median of 5.1 BSIs per 1,000 umbilical or central-catheter days for the ≥1,500 gram birthweight group and 14.6 BSIs per 1,000 umbilical or central-catheter days for the <1,500 gram birthweight group over the same period.[321] Birthweight and device utilization were important determinants of a NICU infant's risk for acquiring BSI.[321] Others have shown receipt of intravenous lipids to also be an important risk factor for the acquisition of CR–BSI, particularly CoNS BSIs, among neonates.[86]

Cronin studied 376 catheters, of varying types, to determine the incidence of catheter colonization and CR–BSI among NICU patients.[322] The incidence of catheter colonization varied by type of catheter, site of insertion, and duration of catheterization. Consistent with the findings of other investigators, the rate

of catheter colonization was significantly lower among patients receiving systemic antimicrobials, having birthweight ≥1500 gm, and not receiving parenteral nutrition. In general, the colonization rates detected in this study were higher than those previously reported for catheters in adults and children.[17] [148] [311] [312] However, the authors could not conclusively determine the relationship of catheter colonization to BSI.

Peripheral venous catheters. As in adults, the use of peripheral venous catheters in pediatric patients may be complicated by phlebitis, extravasation, and catheter colonization. Garland et al. prospectively studied 654 peripheral Teflon catheters in PICU patients to determine the incidence of and risk factors for each of these complications.[311] Of the 654 catheters studied, 83 (13%) were associated with phlebitis. Catheter location, infusion of hyperalimentation fluids with continuous intravenous lipid emulsions, and length of ICU stay before catheter insertion were all factors that increased a patient's risk for phlebitis. However, contrary to the studies among adults, the risk of phlebitis did not increase with the duration of cannulation. The overall incidence of phlebitis in this ICU population (13%) was comparable to that reported in general pediatric patients (10%); for children >10 years of age the incidence of phlebitis (21%) was comparable to that reported for adults[169] and older children.[323]

Of 459 peripheral venous catheters cultured by Garland, 54 (11.8%) were colonized. However, only one (1.9%) of these colonized catheters was associated with CR–BSI. In an earlier study, comparable rates of catheter colonization (10.4%) were found for Teflon peripheral catheters (n=115) used in patients on general pediatric wards.[312] Time in place was the single most important predictor of subsequent catheter colonization, with the incidence of colonization increasing threefold after catheters remained in place >144 hours.[311] Between 48 and 144 hours, the catheter colonization rate was stable at 11%. Other factors significantly but less strongly associated with catheter colonization were patient age and receipt of lipid emulsions. Catheters inserted emergently were no more prone to colonization than were those inserted electively.[311]

Extravasation, the most frequent complication, occurred with 28% of catheters. Several risk factors for extravasation were identified, including patient age (≤1 year), receipt of anticonvulsant, and duration of catheterization (≤72 hours); the risk of

extravasation decreased significantly after the catheter was in place for ≥72 hours.[311]

There are limited data examining the relationship of catheter material to the risk of infection among pediatric patients. In one study of premature infants, Teflon catheters and steel needles used in scalp veins had a comparable risk of infection. However, Teflon catheters had a significantly longer survival than did steel needles.[313]

Peripheral arterial catheters. In a prospective study using semiquantitative culture of 340 peripheral arterial catheters, Furfaro identified two risk factors for CRI: (1) use of an arterial system of a certain design, and (2) duration of catheterization.[314] The implicated arterial system (system A) contained a stopcock and a 120-cm pressure tubing through which blood was drawn back to clear the line of heparin before taking a sample. The alternate system (system B), with a significantly lower risk of infection, contained a one-way valve that did not permit blood backflow into the tubing. The authors noted that the implicated arterial system (A) was the design most widely used in U.S. hospitals.[314]

Although there was a correlation between duration of catheterization and risk of catheter colonization, the risk remained constant for 2–20 days at 6.2%. Catheters in place ≤48 hours had a zero risk of colonization.[314]

Umbilical catheters (UCs). Although the umbilical stump becomes heavily colonized soon after birth, umbilical vessel catheterization is often used for vascular access in newborn infants because umbilical vessels are easily cannulated, allow for delivery of intravenous fluids/medications, permit easy collection of blood samples, and permit measurement of hemodynamic status. Studies of the infectious complications associated with UCs indicate that the incidences of catheter colonization and BSI appear to be similar for umbilical vein catheters (UVC) and umbilical artery catheters (UAC). The incidences of colonization reported among UACs have ranged from 40 to 55%;[324] [325] those among UVCs have varied between 22% and 59%.[324–326] The incidences of BSI detected for the two types of catheters are also similar, 5% for UACs and 3%-8% for UVCs.[324] [326] However, the risk factors for infection appear to differ for the two types of catheters.

Landers et al. found that neonates with very low birthweight and prolonged receipt of antimicrobials were at increased risk for UAC-related BSIs. In contrast, those with higher

birthweight and receipt of parenteral nutrition fluids were at increased risk for UVC-related BSI; duration of catheterization was not an independent risk factor for infection either type of umbilical catheter.[324]

In addition to the risk of endemic infection, umbilical vessel catheterization has been associated with epidemics among critically ill NICU infants. Solomon et al. reported an outbreak of C. parapsilosis fungemia among NICU infants[41] in which duration of umbilical artery catheterization, prolonged receipt of parenteral nutrition, and low gestational age were risk factors for fungemia.[41]

Several investigators have reported lower rates of UC colonization among infants or neonates receiving systemic antimicrobials during umbilical catheterization.[315] [325] [326] However, the one prospective study of prophylactic antimicrobials in patients with chronic UACs found no clear benefit to this therapy.[327]

Central venous catheters. The use of indwelling catheters (e.g., Hickmans and Broviacs, TIDs) in children has become increasingly important over the past decade for the treatment of children with chronic medical conditions, especially malignancies. The Broviac, rather than the Hickman, catheter is preferentially used in children because of its smaller diameter; TIDs may be particularly advantageous in younger pediatric patients (<age 2) where external catheter segments may be contiguous with the diaper area and thus easily contaminated.[73] [328] [329]

Although data from the Children's Cancer Study Group suggest that as many as 18% of all chronic venous access devices in children are removed due to infection,[330] the use of these devices in children have generally been associated with low rates of infections.[64] [66] [71] [73] [77] [331] [332] Several factors have been associated with an increased risk of infection among children with indwelling CVCs, including younger age (<2 years), underlying malabsorption syndrome, and receipt of TPN.[333] Although Indwelling CVCs are largely used in immunocompromised patients for the administration of chemotherapy, neutropenia has not, in children, been shown to increase the risk of infection associated with these devices.[334]

As with adults, the relative merits and risk associated with the use of long-term vascular access devices in children have been the source of considerable investigation. In most studies, TIDs had longer survival and fewer infectious complications than other tunneled catheters. In one study in which the

potentially confounding variables of patient age, underlying diagnosis, and therapy were controlled for in a matched analysis, Hickmans and TIDs were associated with comparable rates of infection. Broviacs still had a higher rate of infection than TIDs, but this difference was only significant after 400 days of catheterization.[335]

Because of the limited vascular sites, the required frequency of catheter change in children is particularly important. Stenzel examined the frequency of catheter change in PICU patients by using survival analysis techniques. In that study of 395 CVCs, catheters remained free of infection for a median of 23.7 days. More importantly, there was no relationship between duration of catheterization and the daily probability of infection (r=0.21, p>0.1), suggesting that routine catheter replacement would not be expected to reduce the incidence of CRI.[336]

Results of prospective randomized trials examining the effect dressing regimens, frequency of catheter and administration sets changes, or use of newer antimicrobial-coated catheters in reducing the incidence of CRI among pediatric patients have not been published.

Table 1

Definitions for Catheter-Related Infection

Colonized catheter: growth of >15 colony forming units from a proximal or distal catheter segment in the absence of accompanying clinical symptoms.

Exit-site infection: erythema, tenderness induration, and/or purulence within 2cm of the skin at the exit site of the catheter.

Pocket infection: erythema and necrosis of the skin over the reservoir of a totally implantable device and/or purulent exudate in the subcutaneous pocket containing the reservoir.

Tunnel infection: erythema, tenderness, and induration in the tissues overlying the catheter and >2cm from the exit site.

Catheter-related bloodstream infection (CR–BSI): isolation of the same organism (i.e., identical species, antibiogram) from a semiquantitative or quantitative culture of a catheter segment and from the blood (preferably drawn from a peripheral vein) of a patient with accompanying clinical symptoms of BSI and no other apparent source of infection. In the absence of laboratory confirmation, defervescence after removal of an implicated catheter from a patient with BSI may be considered indirect evidence of CR–BSI.

Infusate-related bloodstream infection: isolation of the same organism from infusate and from separate percutaneous blood cultures, with no other identifiable source of infection.
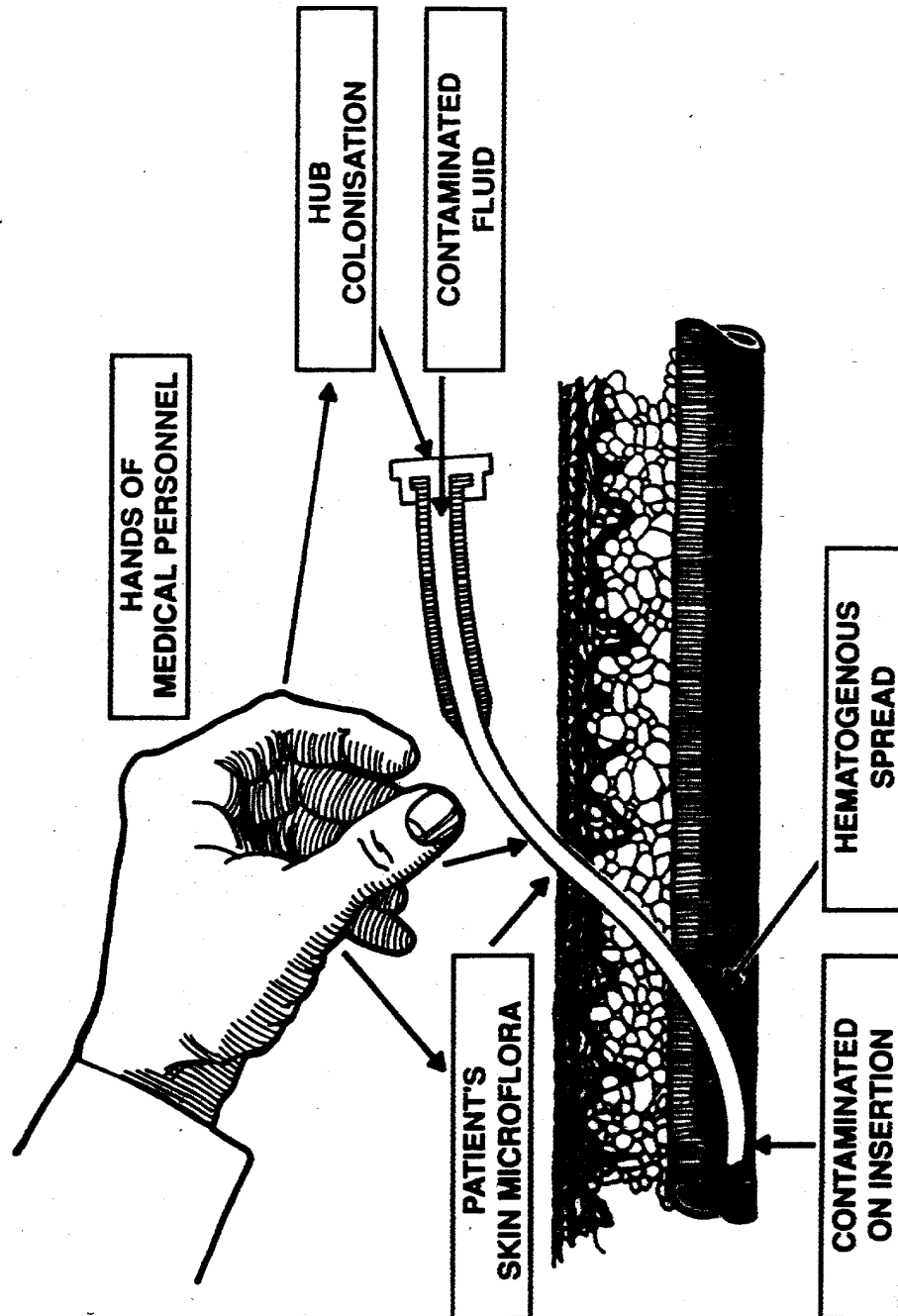
Table 2

Factors Associated With Infusion-Related Phlebitis Among Patients With Peripheral Venous Catheters

Catheter material
Catheter size
Site of catheter insertion
Experience of personnel inserting catheter
Duration of catheterization
Composition of infusate
Frequency of dressing change
Catheter-related infection
Skin prep
Host factors
Emergency room insertion

BILLING CODE 4163–18–P

EXECUTIVE CORRESPONDENCE

Figure 1. Potential Sources for Contamination of Intravascular Devices

HUB COLONISATION

CONTAMINATED FLUID

HANDS OF MEDICAL PERSONNEL

HEMATOGENOUS SPREAD

PATIENT'S SKIN MICROFLORA

CONTAMINATED ON INSERTION

Part 2. Recommendations for the Prevention of Nosocomial Intravascular Device-Related Infections

Contents

I. Introduction

This guideline presents general recommendations for intravascular-device use in all patients, device-specific recommendations, and recommendations for special circumstances, i.e., intravascular-device use in pediatric patients, and central venous catheter use for parenteral nutrition administration and hemodialysis access.

As in previous CDC guidelines, each recommendation is categorized on the basis of existing scientific data, theoretical rationale, applicability, and economic impact. However, the previous CDC system for categorizing recommendations has been modified as follows:

Category IA. Strongly recommended for all hospitals and strongly supported by well-designed experimental or epidemiologic studies.

Category IB. Strongly recommended for all hospitals and viewed as effective by experts in the field and a consensus of HICPAC based on strong rationale and suggestive evidence, even though definitive scientific studies may not have been done.

Category II. Suggested for implementation in many hospitals. Recommendations may be supported by suggestive clinical or epidemiologic studies, a strong theoretical rationale, or definitive studies applicable to some, but not all, hospitals.

No Recommendation; Unresolved Issue. Practices for which insufficient evidence or consensus regarding efficacy exists.

II. General Recommendations for Intravascular-Device Use

A. Health Care Worker Education and Training

Conduct ongoing education and training of health care workers regarding indications for the use of and procedures for the insertion and maintenance of intravascular devices, and appropriate infection control measures to prevent intravascular device-related infections. [285 337 338]

Category IA

B. Surveillance

1. Conduct surveillance for intravascular device-related infections to determine device-specific infection rates, monitor trends in those rates, and assist in identifying lapses in infection control practices within one's own institution. Express data as the number of catheter-related infections or catheter-related bloodstream infections per 1000 catheter-days to facilitate comparisons with national trends. [7 339–341]

Category II

2. Palpate the catheter insertion site for tenderness daily through the intact dressing.

Category IB

3. Visually inspect the catheter site if the patient develops tenderness at the insertion site, fever without obvious source, or symptoms of local or bloodstream infection.

Category IB

4. In patients who have large, bulky dressings that prevent palpation or direct visualization of the catheter-insertion site, remove the dressing and visually inspect the catheter site at least daily and apply a new dressing.

Category II

5. Record the date and time of catheter insertion in a obvious location near the catheter-insertion site (e.g., on the dressing or on the bed).

Category IB

6. Do not routinely perform surveillance cultures of patients or of devices used for intravascular access.

Category IB

C. Handwashing

Wash hands using an antiseptic-containing product before palpating, inserting, changing, or dressing any intravascular device.

Category II

D. Barrier Precautions During Catheter Insertion and Care

1. Wear vinyl or latex gloves when inserting an intravascular catheter as required by the Occupational Safety and Health Administration (OSHA) Bloodborne Pathogens Standard. [342]

Category IB

2. Wear vinyl or latex gloves when changing the dressings on intravascular catheters. [342]

Category IB

3. NO RECOMMENDATION for the use of sterile versus nonsterile gloves during dressing changes.

Unresolved Issue

E. Catheter-Site Care

1. Cutaneous Antisepsis and Antimicrobial Ointments

Cleanse the skin site with an appropriate antiseptic including 70% alcohol, 10% povidone-iodine, or 2% tincture of iodine before catheter insertion. [269] (EXCEPTION: see umbilical catheter section)

Category IA

2. Catheter-Site Dressing Regimens

a. Use either a sterile gauze or transparent dressing to cover the catheter site. [10 165 211 268]

Category IA

b. Leave dressings in place until the catheter is removed, or changed, or the dressing becomes damp, loosened, or soiled. Change dressings more frequently in diaphoretic patients. [165]

Category IB

F. Changing Intravenous Catheters and Administration Sets

1. Remove an intravascular device as soon as its use is no longer clinically indicated.

Category IA

2. Change intravenous tubing, including "piggyback" tubing no more frequently than at 72-hour intervals, unless clinically indicated. [173–175] (Exception: See F3 Below)

Category IA

3. No Recommendation for intravenous tubing changes beyond 72-hour intervals.

Unresolved Issue

4. Change tubing used to administer blood, blood products, or lipid emulsions within 24 hours of completing the infusion. [178 179]

Category IB

G. Preparation and Quality Control of Intravenous Admixtures

1. Admix all parenteral fluids in the pharmacy in a laminar-flow hood using aseptic technique.

Category II

2. Check all containers of parenteral fluid for visible turbidity, leaks, cracks, particulate matter, and the manufacturer's expiration date before use.

Category IA

3. Use single-dose vials for parenteral additives or medications whenever possible. [256 257 259]

Category II

4. If Multidose Vials are Used:

a. Refrigerate multidose vials after they are opened unless otherwise specified by the manufacturer. [258]

Category II

b. Cleanse the rubber diaphragm of multidose vials with alcohol before inserting needle into the vial. [343]

Category IA

c. Use a sterile needle and syringe each time a multidose vial is accessed and avoid touch contamination of the needle prior to penetrating the rubber diaphragm. [259 344–346]

Category IA

d. Discard multidose-vials when empty, when suspected or visible contamination occurs, or when the manufacturer's stated expiration date is reached. [256–259]

Category IA

H. "Hang Time" for Parenteral Fluids

1. Do not leave parenteral nutrition fluids hanging for longer than 24 hours. [347 348]

Category IA

2. No Recommendation for the "hang time" of intravenous fluids other than parenteral nutrition fluids.

Unresolved Issue

I. In-Line Filters

Do not routinely use filters for infection control purposes. [220 222–224]

Category IA

J. Intravenous Therapy Personnel

Designate trained personnel for the insertion and maintenance of intravascular devices. [229–231]

Category IB

K. Needleless Intravascular Devices

No Recommendation for use, maintenance, or frequency of change of needleless intravascular devices.

Unresolved Issue

L. Prophylactic Antimicrobials

Do not routinely administer antimicrobials for prophylaxis of catheter colonization or bloodstream infection before insertion or during use of an intravascular device. [69 234 235]

Category IB

III. Peripheral Venous Catheters

A. Selection of Catheter

1. Select catheters based on the intended purpose and duration of use, known complications (e.g., phlebitis and infiltration), and experience at the institution. Use a Teflon catheter, a polyurethane catheter, or a steel needle. [12 17 165 168 169]

Category IB

2. Avoid the use of steel needles for the administration of fluids/medications that may cause tissue necrosis if extravasation occurs. [169]

Category IA

3. No Recommendation for the use of antimicrobial-impregnated peripheral venous catheters.

Unresolved Issue

B. Selection of Catheter-Insertion Site

1. In adults, use an upper extremity site in preference to one on a lower extremity for catheter insertion. Transfer a catheter inserted in a lower extremity site to an upper extremity site as soon as the latter is available. [160–164]

Category IA

2. In pediatric patients, insert catheters into a scalp, hand, or foot site in preference to a leg, arm, or antecubital fossa site. [311]

Category II

C. Catheter Changes

1. In adults, change peripheral venous catheters and rotate peripheral venous sites every 48–72 hours to minimize the risk of phlebitis. [12 165 168]

Category IB

2. In adults, remove catheters inserted under emergency conditions, where breaks in aseptic technique are likely to have occurred. Insert a new catheter at a different site within 24 hours.

Category IB

3. In pediatric patients, No Recommendation for the frequency of change of peripheral venous catheters.

Unresolved Issue

4. In pediatric patients, No Recommendation for removal of catheters inserted under emergency conditions, where breaks in aseptic technique are likely to have occurred.

Unresolved Issue

5. No Recommendation for the frequency of change of midline catheters.

Unresolved Issue

6. Remove peripheral venous catheters when the patient develops signs of phlebitis (i.e., warmth, tenderness, erythema, palpable venous cord) at the insertion site. [11 12 148]

Category IA

D. Catheter and Catheter-Site Care

1. Flush Solutions, Anticoagulants and Other Intravenous Additives

a. Routinely flush peripheral venous heparin locks with normal saline unless they are used for obtaining blood specimens in which case a dilute heparin (10 units per ml) flush solution should be used. [241 349]

Category IB

b. No Recommendation for the routine application of topical nitrates near the insertion site of peripheral venous catheters.[249 250 252]

Unresolved Issue

2. Cutaneous Antiseptics and Antimicrobial Ointments

No Recommendation for the routine application of topical antimicrobial ointment to the insertion site of peripheral venous catheters.[197 198 200]

Unresolved Issue

IV. Central Venous and Arterial Catheters

A. Selection of Catheter

1. Use a single-lumen central venous catheter unless multiple ports are essential for the management of the patient.[26–29]

Category IB

2. Use tunneled catheters (e.g., Hickman or Broviac) or implantable vascular access devices (i.e., ports) for patients ≥4 years of age in whom long-term vascular access (>30 days) is anticipated.[61–63, 68, 72, 73, 350] Use totally implantable access devices for younger pediatric patients (age <4) who require long-term vascular access.[71, 73, 332, 351, 352]

Category IA

3. In adults, consider use of a silver-impregnated, collagen-cuffed or antimicrobial-impregnated central venous catheter if, after full adherence to other catheter infection control measures (e.g., maximal barrier precautions), there is still an unacceptably high rate of infection.[201, 225, 228] Designate trained personnel to insert cuffed catheters to ensure maximal efficacy and prevent possible extrusion.[201, 225]

Category II

4. In pediatric patients, No Recommendation for the use of antimicrobial/antiseptic-impregnated central venous catheters.

Unresolved Issue

B. Selection of Catheter-Insertion Site

1. Use subclavian, rather than jugular or femoral, sites for central venous catheter placement unless medically contraindicated (e.g., coagulopathy).[31–35]

Category IB

2. No Recommendation on preferred site for insertion of pulmonary artery (Swan-Ganz) catheters.[36–40]

Unresolved Issue

C. Barrier Precautions During Catheter Insertion

Use sterile technique including a sterile gown and gloves, a mask, and a large sterile drape for the insertion of central venous catheters. Use these precautions even if the catheter is inserted in the operating room.[36, 203]

Category IB

D. Catheter Changes

1. No Recommendation for the frequency of routine changes of dressings used on central venous catheter sites.[268]

Unresolved Issue

2. No Recommendation for frequency of change of totally implantable devices (i.e., ports) or the needles used to access them.

Unresolved Issue

3. Change peripherally inserted central venous catheters at least every 6 weeks.[59]

Category IB

4. No Recommendation for the frequency of change of peripherally inserted central venous catheters when the duration of therapy is expected to exceed 6 weeks.

Unresolved Issue

5. Change pulmonary artery catheters at least every 5 days.[21 36 37]

Category IB

6. No Recommendation for the removal of central catheters inserted under emergency conditions, where breaks in aseptic technique are likely to have occurred.

Unresolved Issue

7. Do not routinely change percutaneously inserted central venous catheters by any means as a method to prevent catheter-related infections.[186 187 357]

Category IA

8. Use guidewire-assisted catheter exchange to replace a malfunctioning catheter or to convert an existing catheter if there is no evidence of infection at the catheter site.[131 153 186–190]

Category IB

9. If catheter-related infection is suspected, but there is no evidence of local catheter-related infection (e.g., purulent drainage, erythema, tenderness), change the catheter over a guidewire. Send the removed catheter for semiquantitative or quantitative culture. Leave the newly inserted catheter in place if the catheter culture is negative. If the catheter culture indicates colonization/infection, remove the newly inserted catheter and insert a new catheter at a different site.[131 153 187 188]

Category IB

10. Do not use guidewire-assisted catheter exchange whenever catheter-related infection is documented. If the patient requires continued vascular access, remove the implicated catheter and replace it with another catheter at a different insertion site.[131, 153, 187, 188]

Category IA

E. Catheter and Catheter-Site Care

1. General Measures

a. Do not use parenteral nutrition catheters for purposes other than hyperalimentation (e.g., administration of fluids, blood/blood products).[167 224 264 265]

Category IA

b. No Recommendation for obtaining blood samples for culture through central venous or central arterial catheters.[353–356]

Unresolved Issue

2. Flush Solutions, Anticoagulants, and other Intravenous Additives

Flush indwelling central venous catheters (e.g., Hickman and Broviac) routinely with an anticoagulant. Groshongs do not require routine flushing with an anticoagulant.[62 64–66 69]

Category IB

3. Cutaneous Antiseptics and Antimicrobial Ointments

a. Do not routinely apply antimicrobial ointment to central venous catheter-insertion sites.[30 200]

Category IB

b. Do not apply organic solvents (e.g., acetone or ether) to the skin before insertion of parenteral nutrition catheters.[270]

Category IA

4. Catheter-Site Dressing Regimens

Change catheter-site dressings when they become damp, soiled, or loose or if inspection of the site or catheter change is necessary.

Category IA

V. Additional Recommendations for Central Venous Hemodialysis Catheters

A. Selection of Catheter

Use cuffed central venous catheters for hemodialysis if the period of

temporary access is anticipated to be ≥1 month.[286][295]

Category IB

B. Selection of Catheter-Insertion Site

No Recommendation for the site of insertion of central venous hemodialysis catheters.

Unresolved Issue

C. Catheter Changes

1. No Recommendation for the frequency of routine changes of dressings used on hemodialysis catheter sites.

Unresolved Issue

2. No Recommendation for the removal of hemodialysis catheters when a patient develops fever without an obvious source.

Unresolved Issue

D. Catheter and Catheter-Site Care

1. General Measures

a. Do not use hemodialysis catheters for purposes other than hemodialysis (e.g., administration of fluids, blood/ blood products, or parenteral nutrition).

Category II

b. Restrict manipulations of the hemodialysis catheter, including dressing changes, to trained dialysis personnel.[285]

Category IB

2. Cutaneous Antiseptics and Antimicrobial Ointments

Apply povidone-iodine ointment to the catheter insertion site before and after hemodialysis.[304]

Category IB

VI. Peripheral Arterial Catheters and Pressure-Monitoring Devices

A. Selection of Pressure-Monitoring System

Use disposable, rather than reusable, transducer assemblies when possible.[45][47][58]

Category IA

B. Catheter and Pressure-Monitoring System Changes

1. *In adults,* change peripheral arterial catheters and rotate catheter-insertion sites every 4 days.[20][21]

Category IB

2. *In pediatric patients,* No Recommendation for the frequency of change of peripheral arterial catheters.

Unresolved Issue

3. Replace disposable or reusable transducers at 96-hour intervals. Replace other components of the system, including the tubing, continuous-flush device, and flush solution at the time the transducer is changed.[47][58]

Category IB

4. Replace the arterial catheter and the entire monitoring system if the patient develops a bacteremia while the catheter is in place, irrespective of the source of bacteremia. The catheter and monitoring system should be replaced 24 to 48 hours after antimicrobial therapy has been started.[42][47]

Category IB

C. Care of Pressure-Monitoring Systems

1. General Measures

a. Keep sterile all devices and fluids that come into contact with the fluid of the pressure-monitoring circuit (e.g., calibration devices, heparinized saline).[43][49][55][56]

Category IA

b. Minimize the number of manipulations and entries into the pressure-monitoring system. Use a closed-flush system (i.e., continuous flush), rather than an open system (i.e., one that requires a syringe and stopcock), to maintain the patency of the pressure-monitoring catheters. If stopcocks are used, treat them as a sterile field and cover them with a cap or syringe when not in use.[47][57]

Category IA

c. When the pressure monitoring system is accessed through a rubber diaphragm rather than a stopcock, wipe the diaphragm with an appropriate antiseptic before and after accessing the system.[183]

Category IA

d. Do not administer dextrose-containing solutions or parenteral nutrition fluids through the pressure-monitoring circuit. Use only heparinized normal saline.[47]

Category IA

e. Do not routinely use pressure-monitoring devices to obtain blood cultures.[47]

Category IB

2. Sterilization or Disinfection of Pressure-Monitoring Systems

a. Clean reusable transducers first with soap and water and then sterilize with ethylene oxide or subject to high-level disinfection when: (1) The transducer is used between patients, (2) the transducer is reused on a single patient who requires prolonged pressure monitoring, or (3) the monitoring circuit (including chamber-dome and continuous flow device) is replaced.[47][54] Because transducers differ in design, consult the manufacturers' instructions for detailed reprocessing recommendations.

Category IA

b. Sterilize and disinfect transducers in a central processing area. Reprocess and disinfect reusable transducers in patient care areas only in emergency situations.[47]

Category IB

VII. Additional Recommendations for Umbilical Catheters

A. Catheter Changes

1. No Recommendation for the frequency of change of umbilical catheters.

Unresolved Issue

2. No Recommendation for the removal or exchange of umbilical vein catheters when the patient develops a fever without an obvious source.

Unresolved Issue

B. Catheter-Site Care

1. Cleanse the umbilical insertion site with an appropriate antiseptic, including alcohol or 10% povidone-iodine before catheter insertion.[322][324][325] Do not use tincture of iodine because of the potential effect on the neonatal thyroid.

Category IB

2. No Recommendation for the routine application of polymicrobial ointment to umbilical catheter insertion sites.

Unresolved Issue

APPENDIX.—SUMMARY OF RECOMMENDED PROCEDURES FOR MAINTENANCE OF INTRAVASCULAR CATHETERS, ADMINISTRATION SETS AND PARENTERAL FLUIDS

Frequency of catheter/device change	Frequency of dressing change	Frequency of administration set change	"Hang time" for parenteral fluids	Use of antimicrobial ointments
Peripheral Venous Catheters:				
In adults, change catheter and rotate site every 48–72 hours. Replace catheters inserted under emergency conditions within 24 hours.	Leave dressings in place until the catheter is removed, or changed, or the dressing becomes damp, loosened, or soiled.	Change intravenous tubing, including "piggyback" tubing no more frequently than at 72-hour intervals.	Do not leave parenteral nutrition fluids hanging >24 hours.	NO RECOMMENDATION for the routine application of antimicrobial ointments to catheter site.
In pediatric patients, NO RECOMMENDATION for the frequency of catheter change or for the removal of catheters inserted under emergency conditions.	....	NO RECOMMENDATION for intravenous tubing changes beyond 72-hour intervals. Change tubing used to administer blood, blood products, or lipid emulsions within 24 hours of completing the infusion.	NO RECOMMENDATION for the "hang time" of intravenous fluids other than parenteral nutrition fluids.	
Peripheral Arterial Catheters and Pressure-monitoring Devices:				
In adults, change catheter and rotate insertion sites every 4 days. In pediatric patients, NO RECOMMENDATION for the frequency of catheter change.	Leave dressing in place until the catheter is removed, or changed, or the dressing becomes damp, loosened, or soiled.	Change intravenous tubing, including "piggyback" tubing no more frequently than at 72-hour intervals.	Do not administer dextrose-containing solutions or parenteral nutrition fluids through the pressure monitoring circuit. Use only heparinized normal saline.	NO RECOMMENDATION for the routine application of antimicrobial ointments to catheter site.
Replace disposable or reusable transducers at 96-hour intervals. Replace other components of the system, including the tubing, continuous-flush device and flush solution at the time the transducer is changed.	....	NO RECOMMENDATION for intravenous tubing changes beyond 72-hour intervals.	NO RECOMMENDATION for the "hang time" of heparinized normal saline.	
Midline Catheters:				
NO RECOMMENDATION for the frequency of catheter change.	Leave dressing in place until the catheter is removed, or changed, or the dressing becomes damp, loosened, or soiled.	Change intravenous tubing, including "piggyback" tubing no more frequently than at 72-hour intervals. NO RECOMMENDATION for intravenous tubing changes beyond 72-hour intervals. Change tubing used to administer blood, blood products, or lipid emulsions within 24 hours of completing the infusion.	Do not leave parenteral nutrition fluids hanging >24 hours. NO RECOMMENDATION for the "hang time" of intravenous fluids other than parenteral nutrition fluids.	NO RECOMMENDATION for the routine application of antimicrobial ointments to catheter site.

APPENDIX.—SUMMARY OF RECOMMENDED PROCEDURES FOR MAINTENANCE OF INTRAVASCULAR CATHETERS, ADMINISTRATION SETS AND PARENTERAL FLUIDS—Continued

Frequency of catheter/device change	Frequency of dressing change	Frequency of administration set change	"Hang time" for parenteral fluids	Use of antimicrobial ointments
Central Venous Catheters (nontunneled catheters and tunneled catheters [Hickmans, Groshongs, Ports]:				
Do not routinely change percutaneously inserted (nontunneled) central venous catheters by either rotating insertion sites or by guidewire-assisted catheter exchange.	Leave dressing in place until he catheter is removed, or change, or the dressing becomes damp, loosened, or soiled.	Change intravaneous tubing, including "piggyback tubing" no more frequently than at 72-hour intervals.	Do not leave parenteral nutrition fluids hanging >24 hours.	Do not routinely apply antimicrobial ointment to catheter insertion site.
NO RECOMMENDATION for frequency of change of tunneled catheters, totally implantable devices (i.e., ports), or the needles used to access them.	NO RECOMMENDATION for the frequency of routine changes of dressing used on catheter site.	NO RECOMMENDATION for intravenous tubing changes beyond 72-hour intervals. Change tubing used to administer blood, blood products, or lipid emulsions within 24 hours of completing the infusion.	NO RECOMMENDATION for the "hang time" of intravenous fluids other than parenteral nutrition fluids.	
Peripherally Inserted Central Venous Catheters:				
Change at least every 6 weeks. NO RECOMMENDATION for frequency of change when the duration of therapy is expected to exceed 6 weeks.	Leave dressing in place until the catheter is removed, or changed, or the dressing becomes damp, loosened, or soiled. NO RECOMMENDATION for the frequency of routine changes of dressing used on catheter site.	Change intravenous tubing, including "piggyback" tubing no more frequently than at 72 hour intervals. NO RECOMMENDATION for intravenous tubing changes beyond 72-hour intervals. Change tubing used to administer blood, blood products, or lipid emulsions within 24 hours of completing the infusion.	Do not leave parenteral nutrition fluids hanging >24 hours. NO RECOMMENDATION for the "hang time" of intravenous fluids other than parenteral nutrition fluids.	Do not routinely apply antimicrobial ointment to catheter insertion site.
Central Arterial Catheters (pulmonary artery catheters):				
Change catheter at least every 5 days.	Leave dressing in place until the catheter is removed, or changed, or the dressing becomes damp, loosened, or soiled. NO RECOMMENDATION for the frequency of routine changes of dressing used on catheter site.	Change intravenous tubing, including "piggyback" tubing no more frequently than at 72 hour intervals. NO RECOMMENDATION for intravenous tubing changes beyond 72-hour intervals.	NO RECOMMENDATION for the "hang time" of intravenous fluids other than parenteral nutrition fluids.	Do not routinely apply antimicrobial ointment to catheter insertion site.
Central Hemodialysis Catheters:				
NO RECOMMENDATION for the frequency of catheter change.	Leave dressing in place until the catheter is removed, or changed, or the dressing becomes damp, loosened, or soiled. NO RECOMMENDATION for the frequency of dressing change.	NOT APPLICABLE (Do not use hemodialysis catheters for purposes other than hemodialysis [e.g., administration of fluids, blood/blood products, or parenteral nutrition).	NOT APPLICABLE (Do not use hemodialysis catheters for purposes other than hemodialysis [e.g., administration of fluids, blood/blood products, or parenteral nutrition).	Apply povidone-iodine ointment to the catheter insertion site before and after hemodialysis.

APPENDIX.—SUMMARY OF RECOMMENDED PROCEDURES FOR MAINTENANCE OF INTRAVASCULAR CATHETERS, ADMINISTRATION SETS AND PARENTERAL FLUIDS—Continued

Frequency of catheter/device change	Frequency of dressing change	Frequency of administration set change	"Hang time" for parenteral fluids	Use of antimicrobial ointments
Umbillical Catheters: NO RECOMMENDATION for frequency of catheter change.	NOT APPLICABLE	Change intravenous tubing, including "piggyback tubing" no more frequently than at 72-hour intervals. NO RECOMMENDATION for intravenous tubing changes beyond 72-hour intervals. Change tubing used to administer blood, blood products or lipid emulsions within 24 hours of completing the infusion.	Do not leave parenteral nutrition fluids hanging >24 hours. NO RECOMMENDATION for the "hang time" of intravenous fluids other than parenteral nutrition fluids.	NO RECOMMENDATION for the routine application of antimicrobial ointments to the catheter site.

References

1. Smith RL, Meixler SM, Simberkoff MS. Excess mortality in critically ill patients with nosocomial bloodstream infections. Chest 1991;100:164–7.

2. Martin MA, Pfaller MA, Wenzel RP. Coagulase-negative staphylococcal bacteremia. Mortality and hospital stay. Ann Intern Med 1989;110:9–16.

3. Haley RW. Estimating the extra charges and prolongation of hospitalization due to nosocomial infections: A comparison of methods. J Infect Dis 1980;141:248–57.

4. Pittet D, Tarara D, Wenzel RP. Nosocomial bloodstream infection in critically ill patients: excess length of stay, extra costs, and attributable mortality. JAMA 1994;162:1598–601.

5. Arnow PM, Quimosing EM, Brech M. Consequences of intravascular catheter sepsis. Clin Infect Dis 1993;16:778–84.

6. Maki DG. Infections due to infusion therapy. In: Bennett JV, Brachman PS, eds. Hospital Infections. Third ed. Boston/Toronto/London: Little, Brown and Company, 1992.

7. Banerjee SN, Emori TG, Culver DH, et al. Secular trends in nosocomial primary bloodstream infection in the United States, 1980–1989. Am J Med 1991;91(Suppl 3B):86S–9S.

8. Jarvis WR, Edwards JR, Culver DH, et al. Nosocomial infection rates in adult and pediatric intensive care units in the United States. Am J Med 1991;91 (Suppl 3B):3B–185S–91S.

9. Gantz NM, Presswood GM, Goldbert R, et al. Effects of dressing type and change interval on intravenous therapy complication rates. Diagn Microbiol Infect Dis 1984;2:325–32.

10. Hoffman KK, Western S, Groschel DHM, et al. Bacterial colonization and phlebitis-associated risk with transparent polyurethane film for peripheral intravenous site dressings. Am J Clin Path 1988;16:101–6.

11. Smallman L, Burdon DW, Alexander-Williams J. The effect of skin preparation and care on the incidence of superficial thrombophlebitis. Br J Surg 1980;67:861–2.

12. Collin J, Collin C, Constable FL, Johnston IDA. Infusion thrombophlebitis and infection with various cannulas. Lancet 1975;2:150–3.

13. Larson E, Hargiss C. A decentralized approach to maintenance of intravenous therapy. Am J Clin Path 1984;8:620–4.

14. Ena J, Cercenado E, Martinez D, et al. Cross-sectional epidemiology of phlebitis and catheter-related infections. Infect Control Hosp Epidemiol 1992;13:15–20.

15. Craven DE, Lichtenberg A, Kunches LM, et al. A randomized study comparing a transparent polyurethane dressing to a dry gauze dressing for peripheral intravenous catheter sites. Infect Control 1985;6:361–6.

16. Tager IB, Ginsberg MB, Ellis SE, et al. An epidemiologic study of the risks associated with peripheral intravenous catheters. Am J Epidemiol 1983;118:839–51.

17. Maki DG, Ringer M. Risk factors for infusion-related phlebitis with small peripheral venous catheters. A randomized controlled trial. Ann Intern Med 1991;114:845–54.

18. Gardner RM, Schwartz R, Wong HC, Burke JP. Percutaneous indwelling radial-artery catheters for monitoring cardiovascular function. N Engl J Med 1974;290:1227–31.

19. Samsoondar W, Freeman JB, Coultish I, Oxley C. Colonization of intravascular catheters in an intensive care unit. Am J Surg 1985;149:730–2.

20. Band JD, Maki DG. Infections caused by arterial catheters used for hemodynamic monitoring. Am J Med 1979;67:735–41.

21. Raad I, Umphrey I, Khan A, Truett LJ, Bodey GP. The duration of placement as a predictor of peripheral and pulmonary arterial catheter infections. J Hosp Infect 1993;23:17–26.

22. Thomas F, Burke JP, Parker J, et al. The risk of infection related to radial vs femoral sites for arterial catheterization. Crit Care Med 1983;11:807–12.

23. Maki DG, McCormick RD, Uman SJ, Wirtanen GW. Septic endarteritis due to intra-arterial catheters for cancer chemotherapy. Cancer 1979;44:1228–40.

24. Pemberton LB, Lyman B, Lander V, Covinsky J. Sepsis from triple- vs single-lumen catheters during total parenteral nutrition in surgical or critically ill patients. Arch Surg 1986;121:591–4.

25. Yeung C, May J, Hughes R. Infection rate for single-lumen vs. triple-lumen subclavian catheters. Infect Control Hosp Epidemiol 1988;9:154–8.

26. Hilton E, Haslett TM, Borenstein MT, et al. Central catheter infections: single-versus triple-lumen catheters. Influence of guide wires on infection rates when used for replacement of catheters. Am J Med 1988;84:667–72.

27. McCarthy MC, Shives JK, Robison RJ, Broadie TA. Prospective evaluation of single- and triple-lumen catheters in total parenteral nutrition. J Parenter Enteral Nutr 1987;11:259–62.

28. Clark-Christoff N, Watters VA, Sparks W, Snyder P, Grant JP. Use of triple-lumen subclavian catheters for administration of total parenteral nutrition. J Parenter Enteral Nutr 1992;16:403–7.

29. Farkas JC, Liu N, Bleriot JP, Chevret S, Goldstein FW, Carlet J. Single- versus triple-lumen central catheter-related sepsis: A prospective randomized study in a critically ill population. Am J Med 1992;93:277–82.

30. Prager RL, Silva J. Colonization of central venous catheters. South Med J 1984;77:458–61.

31. Brun-Buisson C, Abrouk F, Legrand P, Huet Y, Larabi S, Rapin M. Diagnosis of central venous catheter-related sepsis. Critical level of quantitative tip cultures. Arch Intern Med 1987;147:873–7.

32. Collignon P, Soni N, Pearson I, Sorrell T, Woods P. Sepsis associated with central vein catheters in critically ill patients. Intens Care Med 1988;14:227–31.

33. Richet H, Hubert B, Nitemberg G, et al. Prospective multicenter study of vascular catheter-related complications and risk factors for positive central-catheter cultures in intensive care unit patients. J Clin Microbiol 1990;28:2520–5.

34. Horowitz HW, Dworkin BM, Savino JA, et al. Central catheter-related infections: Comparison of pulmonary artery catheters and triple lumen catheters for the delivery of hyperalimentation in a critical care setting. J Parenter Enteral Nutr 1990;14:558–92.

35. Gil RT, Kruse JA, Thill-Baharozian MC, Carlson RW. Triple- vs single-lumen central

venous catheters. A prospective study in a critically ill population. Arch Intern Med 1989;149:1139–43.

36. Mermel LA, McCormick RD, Springman SR, Maki DG. The pathogenesis and epidemiology of catheter-related infection with pulmonary artery Swan-Ganz catheters: a prospective study utilizing molecular subtyping. Am J Med 1991;91:197-205.

37. Rello J, Coll P, Net A, Prats G. Infection of pulmonary artery catheters. Epidemiologic characteristics and multivariate analysis of risk factors. Chest 1993;103:132–6.

38. Singh S, Nelson N, Acosta I, Check FE, Puri VK. Catheter colonization and bacteremia with pulmonary and arterial catheters. Crit Care Med 1982;10:736–9.

39. Pinilla JC, Ross DF, Martin T, Crump H. Study of the incidence of intravascular catheter infection and associated septicemia in critically ill patients. Crit Care Med 1983;11:21–5.

40. Senagore A, Waller JD, Bonnell BW, et al. Pulmonary artery catheterization: A prospective study of internal jugular and subclavian approaches. Crit Care Med 1987;15:35–7.

41. Solomon SL, Alexander H, Eley JW, et al. Nosocomial fungemia in neonates associated with intravascular pressure-monitoring devices. Pediatr Infect Dis 1986;5:680–5.

42. Maki DG, Hassemer CA. Endemic rate of fluid contamination and related septicemia in arterial pressure monitoring. Am J Med 1981;70:733–8.

43. Phillips I, Eykyn S, Curtis MA, Snell JJS. *Pseudomonas cepacia (multivorans)* septicaemia in an intensive care unit. Lancet 1972;i:375–7.

44. Gahrn-Hansen B, Alstrup P, Dessau R, et al. Outbreak of infection with *Achromobacter xilosoxidans* from contaminated intravascular pressure transducers. J Hosp Infect 1988;12:1–6.

45. Villarino ME, Jarvis WR, O'Hara C, Bresnahan J, Clark N. Epidemic of *Serratia marcescens* bacteremia in a cardiac intensive care unit. J Clin Microbiol 1989;27:2433–6.

46. Hekker TAM, Van Overhagen W, Schneider AJ. Pressure transducers: an overlooked source of sepsis in the intensive care unit. Intens Care Med 1990;16:511–2.

47. Mermel LA, Maki DG. Epidemic bloodstream infections from hemodynamic pressure monitoring: signs of the times. Infect Control Hosp Epidemiol 1989;10:47–53.

48. Thomas A, Lalitha MK, Jesudason MY, John S. Transducer-related *Enterobacter cloacae* sepsis in post-operative cardiothoracic patients. J Hosp Infect 1993;25:211–4.

49. Weinstein RA, Emori TG, Anderson RL, Stamm WE. Pressure transducers as a source of bacteremia after open heart surgery. Report of an outbreak and guidelines for prevention. Chest 1976;69:338–44.

50. Weinstein RA, Stamm WE, Kramer L, Corey L. Pressure monitoring devices: overlooked source of nosocomial infection. JAMA 1976;236:936–8.

51. Buxton AE, Anderson RL, Klimek J, Quintiliani R. Failure of disposable domes to prevent septicemia acquired from contaminated pressure transducers. Chest 1978;74:508–13.

52. Donowitz LG, Marsik FJ, Hoyt JW, Wenzel RP. *Serratia marcescens* bacteremia from contaminated pressure transducers. JAMA 1979;242:1749–51.

53. Retailliau HF. Infection control with invasive pressure monitoring devices. Am J Clin Path 1979:13–7.

54. Beck-Sague CM, Jarvis WR. Epidemic bloodstream infections associated with pressure transducers: a persistent problem. Infect Control 1989;10:54–9.

55. Fisher MC, Long SS, Roberts EM, Dunn JM, Balsara RK. *Pseudomonas maltophilia* bacteremia in children undergoing open heart surgery. JAMA 1981;246:1571–4.

56. Stamm WE, Colella JJ, Anderson RL, et al. Indwelling arterial catheters as a source of nosocomial bacteremia—An outbreak caused by Flavobacterium species. N Engl J Med 292;292:1099–102.

57. Shinozaki T, Deane RS, Mazuzan JE, Hamel AJ, Hazelton D. Bacterial contamination of arterial lines. JAMA 1983;249:223–5.

58. Luskin RL, Weinstein RA, Nathan C, Chamberlin WH, Kabins SA. Extended use of disposable pressure transducers: a bacteriologic evaluation. JAMA 1986;255:916–20.

59. Raad I, Davis S, Becker M, et al. Low infection rate and long durability of nontunneled silastic catheters. A safe cost-effective alternative for long-term venous access. Arch Intern Med 1993;153:1791–6.

60. Williams DN, Gibson J, Vos J, Kind AC. Infusion thrombophlebitis and infiltration associated with intravenous cannulae: A controlled study comparing three different cannula types. NITA 1982;5:379–82.

61. Abraham JL, Mullen JL. A prospective study of prolonged central venous access in leukemia. JAMA 1982;248:2868–73.

62. Pessa ME, Howard RJ. Complications of Hickman-Broviac catheters. Surg Gynecol Obstet 1985;161:257–60.

63. Rannem T, Ladefoged K, Tvede M, Lorentzen JE, Jarnum S. Catheter-related septicemia in patients receiving home parenteral nutrition. Scan J Gastroenterol 1986;21:455–60.

64. Dabyshire PJ, Weightman NC, Speller DCE. Problems associated with indwelling central venous catheters. Arch Dis Child;1985;60:129–39.

65. Shulman RJ, Rahmna S, Mahoney D, et al. A totally implanted venous access system used in patients with cancer. Infect Control 1987;3:61–72.

66. Shapiro ED, Wald ER, Nelson KA, et al. Broviac catheter-related bacteremia in oncology patients. Infect Surg 1982;6:103–6.

67. Weightman NC, Simpson EM, Speller DC, Mott MG, Oakhill A. Bacteraemia related to indwelling central venous catheters: prevention, diagnosis and treatment. Eur J Clin Microbiol Infect Dis 1988;7:125–9.

68. Schuman ES, Winters V, Gross GF, Hayes JF. Management of Hickman catheter sepsis. Am J Surg 1985;149:627–8.

69. Press OW, Ramsey PG, Larson EB, Fefer A, Hickman RO. Hickman catheter infections in patients with malignancies. Medicine 1984;63:189–200.

70. Andrivet P, Bacquer A, Ngoc CV, et al. Lack of clinical benefit from subcutaneous tunnel insertion of central venous catheters in immunocompromised patients. Clin Infect Dis 1994;18:199–206.

71. McDowell HP, Hart CA, Martin J. Implantable subcutaneous venous catheters. Arch Dis Child 1986;61:1037–8.

72. Brickner H, Saeter G. Fifty-five patient years' experience with a totally implanted system for intravenous chemotherapy. Cancer 1986;57:1124–9.

73. Wurzel CL, Halom K, Feldman JG, Rubin LG. Infection rates of Broviac-Hickman catheters and implantable venous devices. Am J Dis Child 1988;142:536–40.

74. Pegues D, Axelrod P, McClarren C, et al. Comparison of infections in Hickman and implanted port catheters in adult solid tumor patients. J Surg Oncol 1992;49:156–62.

75. van der Pijl H, Jos Frissen PH. Experience with a totally implantable venous access device (Port-A-Cath) in patients with AIDS. AIDS 1992;6:709–13.

76. Gyves J, Ensminger W, Niederhuber J, et al. A totally-implanted injection port system for blood sampling and chemotherapy administration. JAMA 1984;251:2538–41.

77. Lokich JJ, Bothe A, Benotti P, Moore C. Complications and management of implanted venous access catheters. J Clin Oncol 1985;3:710–7.

78. Kappers-Klunne MC, Degener JE, Stijnen T, Abels J. Complications from long-term indwelling central venous catheters in hematologic malignancy patients with special reference to infection. Cancer 1989;64:1747–52.

79. Carde P, Cosset-Delaigue MF, Laplanche A, Chareau I. Classical external indwelling central venous catheter versus total implanted venous access systems for chemotherapy administration: a randomized trial in 100 patients with solid tumors. Eur J Cancer Clin Oncol 1989;25:939–44.

80. Groeger JS, Lucas AB, Thaler HT, et al. Infectious morbidity associated with long-term use of venous access devices in patients with cancer. Ann Intern Med 1993;119:1168–74.

81. Khoury MD, Lloyd LR, Burrows J, Berg R, Yap J. A totally implanted venous access system for the delivery of chemotherapy. Cancer 1985;56:1231–4.

82. Stillman RI, Wenzel RP, Donowitz LC. Emergence of coagulase negative staphylococci as major nosocomial bloodstream pathogens. Infect Control 1987;8:108–12.

83. Morrison AJ jr, Freer CV, Searcy MA, et al. Nosocomial bloodstream infections: secular trends in a statewide surveillance program in Virginia. Infect Control 1986;7:550–3.

84. Schaberg DR, Culver DH, Gaynes RP. Major trends in the microbial etiology of nosocomial infection. Am J Med 1991;91(suppl 3B):3B72S–75S.

85. Dougherty SH. Pathobiology of infection in prosthetic devices. Rev Infect Dis 1988;10:1102–17.

86. Freeman J, Goldmann DA, Smith NE, et al. Association of intravenous lipid emulsion and coagulase-negative staphylococcal bacteremia in neonatal intensive care units. N Engl J Med 1990;323:301–8.

87. Jarvis WR, Martone WJ. Predominant pathogens in hospital infections. J

Antimicrob Chemother 1992;29 (Suppl A):19–24.

88. Dugdal DC, Ramsey PG. *Staphylococcus aureus* bacteremia patients with Hickman catheters. Am J Med 1990;89:137–41.

89. Libman H, Arbeit RD. Complications associated with *Staphylococcus aureus* bacteremia. Arch Intern Med 1984;144:541–5.

90. Raad I, Narro J, Khan A, Tarrand J, Vartivarian S, Bodey GP. Serious complications of vascular catheter-related *Staphylococcus aureus* bacteremia in cancer patients. Eur J Clin Microbiol Infect Dis 1992;11:675–82.

91. Centers for Disease Control and Prevention. Nosocomial enterococci resistant to vancomycin—United States, 1989–1993. MMWR 1993;42:597–9.

92. Karanfil LV, Murphy M, Josephson A, et al. A cluster of vancomycin-resistant *Enterococcus faecium* in an intensive care unit. Infect Control Hosp Epidemiol 1992;13:195–200.

93. Boyce JM, Opal SM, Chow JW, et al. Outbreak of multidrug-resistant *Enterococcus faecium* with transferable vanB class vancomycin resistance. J Clin Microbiol 1994;32:1148–53.

94. Handwerger S, Raucher B, Altarac D, et al. Nosocomial outbreak due to *Enterococcus faecium* highly resistant to vancomycin, penicillin, and gentamicin. Clin Infect Dis 1993;16:750–5.

95. Rubin LG, Tucci V, Cercenado E, Eliopoulos G, Isenberg HD. Vancomycin-resistant *Enterococcus faecium* in hospitalized children. Infect Control Hosp Epidemiol 1992;13:700–5.

96. Montecalvo MA, Horowitz H, Gedris C, et al. Outbreak of vancomycin-, ampicillin-, and aminoglycoside-resistant *Enterococcus faecium* in an adult oncology unit. Antimicrob Agents Chemother 1994;38:1363–7.

97. Frieden TR, Munsiff SS, Low DE, et al. Emergence of vancomycin-resistant enterococci in New York City. Lancet 1993;342:76–9.

98. Boyle JF, Soumakis SA, Rendo A, et al. Epidemiologic analysis and genotype characterization of a nosocomial outbreak of vancomycin-resistant enterococci. J Clin Microbiol 1993;1993:31.

99. Edmond MB, Ober JF, Weinbaum DL, et al. Vancomycin-resistant *Enterococcus faecium* bacteremia: risk factors for infection. Clin Infect Dis 1995;20:1126–33.

100. Livornese LLJ, Dias S, Samel C, et al. Hospital-acquired infection with vancomycin-resistant *Enterococcus faecium* transmitted by electronic thermometers. Ann Intern Med 1992;117:112–6.

101. Moellering RCJ. Enterococcal infections in patients treated with moxalactam. Rev Infect Dis 1982;(4 suppl):S70–S711.

102. Yu VL. Enterococcal superinfection and colonization after therapy with moxalactam, a new broad-spectrum antibiotic. Ann Intern Med 1981;94:784–5.

103. Feliciano DV, Gentry LO, Bitondo CG, et al. Single agent cephalosporin prophylaxis for penetrating abdominal trauma: results and comment on the emergence of the enterococcus. Am J Surg 1986;152:674–81.

104. Pallares R, Dick R, Wenzel RP, Adams JR, Nettleman MD. Trends in antimicrobial utilization at a tertiary teaching hospital during a 15-year period (1978–1992). Infect Control Hosp Epidemiol 1993;14:376–82.

105. Ena J, Dick RW, Jones RN, Wenzel RP. The epidemiology of intravenous vancomycin usage in a university hospital: a 10-year study. JAMA 1993;269:598–602.

106. Beck-Sagué CM, Jarvis WR. Secular trends in the epidemiology of nosocomial fungal infections in the United States, 1980–1990. J Infect Dis 1993;167:1247–51.

107. Voss A, Hollis RJ, Pfaller MA, Wenzel RP, Doebbeling BN. Investigation of the sequence of colonization and candidemia in nonneutropenic patients. J Clin Microbiol 1994;32:975–80.

108. Pfaller MA, Cabezudo I, Hollis R, Huston B, Wenzel RP. The use of biotyping and DNA fingerprinting in typing *Candida albicans* from hospitalized patients. Diagn Microbiol Infect Dis 1990;13:481–9.

109. Reagan DR, Pfaller MA, Hollis RJ, Wenzel RP. Characterization of the sequence of colonization and nosocomial candidemia using DNA fingerprinting and a DNA probe. J Clin Microbiol 1990;28:2733–8.

110. Moro ML, Maffei C, Manso E, Morace G, Polonelli L, Biavasco F. Nosocomial outbreaks of systemic candidosis associated with parenteral nutrition. Infect Control Hosp Epidemiol 1990;11:27–35.

111. Sherertz RJ, Gledhill KS, Hampton KD, et al. Outbreak of Candida bloodstream infections associated with retrograde medication administration in a neonatal intensive care unit. J Pediatr 1992;120:455–61.

112. Weems JJ, Chamberland ME, Ward J, Willy M, Padnye AA, Solomon SL. *Candida parapsilosis* fungemia associated with parenteral nutrition and contaminated blood pressure transducers. J Clin Microbiol 1987;1925:1029–32.

113. Phelps M, Ayliffe GAJ, Babb JR. An outbreak of candidiasis in a special care baby unit: the use of resistogram typing method. J Hosp Infect 1986;7:13–20.

114. Vaudry WL, Tierney AJ, Wenman WM. Investigation of systemic *Candida albicans* infections in a neonatal intensive care unit. J Infect Dis 1988;158:1375–9.

115. Burnie JP, Odds FC, Lee W, Webster C, Williams JD. Outbreak of systemic *Candida albicans* in an intensive care unit caused by cross infection. Br Med J 1985;290:746–8.

116. Finkelstein R, Reinhertz G, Hashman N, Merzbach D. Outbreak of *Candida tropicalis* fungemia in a neonatal intensive care unit. Infect Control Hosp Epidemiol 1993;14:587–90.

117. Lee W, Burnie JP, Matthews RC, Oppenheim BO, Damani NN. Hospital outbreaks with yeasts. J Hosp Infect 1991;18 (suppl A):237–49.

118. Isenberg HD, Tucci V, Cintron F, Singer C, Weinstein GS, Tyras DH. Single source outbreak of *Candida tropicalis* complicating coronary bypass surgery. J Clin Microbiol 1989;27:2426–8.

119. Hunter PR, Harrison GAJ, Fraser CAM. Cross infection and diversity of *Candida albicans* strain carriage in patients and nursing staff on an intensive care unit. J Med Vet Mycol 1990;28:317–25.

120. Burnie JP. Candida of hands. J Hosp Infect 1986;8:1–4.

121. Doebbeling BN, Hollis RJ, Isenberg HD, Wenzel RP, Pfaller MA. Restriction fragment analysis of a *Candida tropicalis* outbreak of sternal wound infections. J Clin Microbiol 1991;29:1268–70.

122. Burnie JP, Lee W, William JD, Matthews RC, Odds FC. Control of an outbreak of systemic *Candida albicans.* Br Med J [Clin Res] 1985;291:1092–3.

123. Snydman DR, Pober BR, Murray SA, Gorbea HF, Majka JA, Perry LK. Predictive value of surveillance skin cultures in total parenteral nutrition-related infection. Lancet 1982:1385–8.

124. Kelsey MC, Gosling M. A comparison of the morbidity associated with occlusive and non-occlusive dressings applied to peripheral intravenous devices. J Hosp Infect 1984;5:313–21.

125. Bjornson HS, Colley R, Bower RH, Duty VP, Schwartz-Fulton JT, Fischer JE. Association between microorganism growth at the catheter insertion site and colonization of the catheter in patients receiving total parenteral nutrition. Surgery 1982;92:720–7.

126. Cooper GL, Hopkins CC. Rapid diagnosis of intravascular catheter-associated infection by direct gram staining of catheter segments. N Engl J Med 1985;312:1142–47.

127. deCicco M, Chiaradia V, Veronesi A, et al. Source and route of microbial colonization of parenteral nutrition catheters. Lancet 1989;2:1258–61.

128. Linares J, Sitges-Serra A, Garau J, et al. Pathogenesis of catheter sepsis: A prospective study with quantitative and semiquantitative cultures of catheter hub and segments. J Clin Microbiol 1985;21:357–60.

129. Sitges-Serra A, Linares J, Perez JL, et al. A randomized trial on the effect of tubing changes on hub contamination and catheter sepsis during parenteral nutrition. J Parenter Enteral Nutr 1985;9:322–5.

130. Raad I, Casterton W, Sabharwal U, et al. Ultrastructural analysis of indwelling vascular catheters: A quantitative relationship between luminal colonization and duration of placement. J Infect Dis 1993;168:400–7.

131. Pettigrew RA, Lang SDR, Haydock DA, Parry BR, Bremner DA, Hill GL. Catheter-related sepsis in patients on intravenous nutrition: a prospective study of quantitative catheter cultures and guidewire changes for suspected sepsis. Br J Surg 1985;72:52–5.

132. Maki DG, Martin WT. Nationwide epidemic of septicemia caused by contaminated infusion products. IV. Growth of microbial pathogens in fluids for intravenous infection. J Infect Dis 1975;131:267–72.

133. Centers for Disease Control. Nosocomial bacteremia associated with intravenous fluid therapy. MMWR 1971;20 (suppl 9).

134. Maki DG, Anderson RL, Shulamn JA. In-use contamination of intravenous infusion fluid. Appl Microbiol 1974;28:778–84.

135. Sheth NK, Rose HD, Franson TR, et al. In vitro quantitative adherence of bacteria on polyvinyl chloride and Teflon catheters in hospitalized patients. J Clin Microbiol 1983;18:1061–3.

136. Hogt AH, Dankert J, Feijen J. Encapsulation, slime production and surface

hydrophobicity of coagulase-negative staphylococci. FEMS Microbiol Lett 1983;18:211–5.

137. Ashkenazi S, Weiss E, Drucker MM. Bacterial adherence to intravenous catheters and needles and its influence by cannula type and bacterial surface hydrophobicity. J Lab Clin Med 1986;107:136–40.

138. Locci R, Peters G, Pulverer G. Microbial colonization of prosthetic devices I. Microtopographical characteristics of intravenous catheters as detected by scanning microscopy. Zentralbl Bakteriol 1981;173:285–92.

139. Peters G, Locci R, Pulverer G. Microbial colonization of prosthetic devices II. Scanning electron microscopy of naturally infected intravenous catheters. Zentralbl Bakteriol 1981;173:293–9.

140. Stillman RM, Soliman F, Garcia L, et al. Etiology of catheter-associated sepsis: correlation with thrombogenicity. Arch Surg 1977;112:1497–502.

141. Herrmann M, Vaudaux PE, Pittet D, et al. Fibronectin, fibrinogen, and laminin act as mediators of adherence of clinical staphylococcal isolates to foreign material. J Infect Dis 1988;158:693–701.

142. Vaudaux P, Suzuki R, Waldvogel FA, Morgenthaler JJ, Nydegger UE. Foreign body infection: role of fibronectin as a ligand for the adherence of *Staphylococcus aureus.* J Infect Dis 1984;150:546–53.

143. Gristina AG. Biomaterial-centered infection: microbial adhesion versus tissue integration. Science 1987;237:1588–95.

144. Johnson GM, Lee DA, Regelmann WE, Gray ED, Peters G, Quie PG. Interference with granulocyte function by *Staphylococcus epidermidis* slime. Infect Immun 1986;54:13–20.

145. Gray ED, Peters G, Verstegen M, Regelmann WE. Effect of extracellular slime substance from *Staphylococcus epidermidis* on the human cellular immune response. Lancet 1984;1:365–7.

146. Farber BF, Kaplan H, Clogston AG. *Staphylococcus epidermidis* extracted slime inhibits the antimicrobial action of glycopeptide antibiotics. J Infect Dis 1990;161:37–40.

147. Branchini ML, Pfaller MA, Rhine-Chalberg J, Frempong T, Isenberg HD. Genotypic variation in slime production among blood and catheter isolates of *Candida parapsilosis.* J Clin Microbiol 1994;32:452–6.

148. Maki DG, Weise CE, Sarafin HW. A semiquantitative culture method for identifying intravenous catheter-related infection. N Engl J Med 1977;296:1305–9.

149. Zufferey J, Rime B, Francioli P, Bille J. Simple method for rapid diagnosis of catheter-associated infection by direct acridine orange staining of catheter tips. J Clin Microbiol 1988;26:175–7.

150. Cleri DJ, Corrado ML, Seligman SJ. Quantitative culture of intravenous catheters and other intravascular inserts. J Infect Dis 1987;141:781–6.

151. Sherertz RJ, Raad II, Balani A, et al. Three year experience with sonicated vascular catheter cultures in a clinical microbiology laboratory. J Clin Microbiol 1990;28:76–82.

152. Raad II, Sabbagh MF, Rand KH, et al. Quantitative tip culture methods and the diagnosis of central venous catheter-related infections. Diagn Microbiol Infect Dis 1992;15:13–20.

153. Armstrong CW, Mayhall CG, Miller KB, et al. Prospective study of catheter replacement and other risk factors for infection of hyperalimentation catheters. J Infect Dis 1986;154:808–16.

154. Fan ST, Teoh-Chan CH. Evaluation of central venous catheter sepsis by differential quantitative culture. Eur J Clin Microbiol Infect Dis 1989;8:142–4.

155. Armstrong CW, Mayhall CG, Miller KB, et al. Clinical predictors of infection of central venous catheters used for total parenteral nutrition. Infect Control Hosp Epidemiol 1990;11:71–8.

156. Wing EJ, Norden CW, Shadduck RK, Winkelstein A. Use of quantitative bacteriologic techniques to diagnose catheter-related sepsis. Arch Intern Med 1979;139:482–3.

157. Raucher HS, Hyatt AC, Barzilai MB, et al. Quantitative blood cultures in the evaluation of septicemia in children with Broviac catheters. J Pediatr 1984;104:29–33.

158. Flynn PM, Shenep JL, Stokes DC, Barrett FF. In place management of confirmed central venous catheter-related bacteremia. Pediatr Infect Dis J 1987;6:729–34.

159. Ruderman JW, Morgan MA, Klein AH. Quantitative cultures in the diagnosis of sepsis in infants with umbilical Broviac catheters. J Pediatr 1988;112:748–51.

160. Bansmer G, Keith D, Tesluk H. Complications following use of indwelling catheters of inferior vena cava. JAMA 1958;167:1606–11.

161. Phillips RW, Eyre JD. Septic thrombophlebitis with septicemia. N Engl J Med 1958;259:729–31.

162. Indar R. The dangers of indwelling polyethylene cannulae in deep veins. Lancet 1959;1:284–6.

163. McNair TJ, Dudley HA. The local complications of intravenous therapy. Lancet 1959;2:365–8.

164. Crane C. Venous interruption of septic thrombophlebitis. N Engl J Med 1960;262:947–51.

165. Maki DG, Ringer M. Evaluation of dressing regimens for prevention of infection with peripheral intravenous catheters. Gauze, a transparent polyurethane dressing, and an iodophor-transparent dressing. JAMA 1987;258:2396–403.

166. Collins RN, Braun PA, Zinner SH, Kass EH. Risk of local and systemic infection with polyurethane intravenous catheters. N Engl J Med 1968;279:340–3.

167. Maki DG, Goldman DA, Rhame FS. Infection control in intravenous therapy. Ann Intern Med 1973;79:867–87.

168. Band JD, Maki DG. Steel needles used for intravenous therapy. Morbidity in patients with hematologic malignancy. Arch Intern Med 1980;140:31–4.

169. Tully JL, Friedland GH, Baldini LM, Goldmann DA. Complications of intravenous therapy with steel needles and Teflon catheters. A comparative study. Am J Med 1981;70:702–6.

170. Mitchell A, Atkins S, Royle GT, Kettlewell MGW. Reduced catheter sepsis and prolonged catheter life using a tunneled silicone rubber catheter for total parenteral nutrition. Br J Surg 1982;69:420–2.

171. Raad II, Hohn DC, Gilbreath BJ, et al. Prevention of central venous catheter-related infections by using maximal sterile barrier precautions during insertion. Infect Control Hosp Epidemiol 1994;15:231–8.

172. Maki DG. Yes, Virginia, aseptic technique is very important: Maximal barrier precautions during insertion reduce the risk of central venous catheter-related bacteremia. Infect Control Hosp Epidemiol 1994;15:227–30.

173. Snydman DR, Donnelly-Reidy M, Perry LK, Martin WJ. Intravenous tubing containing burettes can be safely changed at 72-hour intervals. Infect Control 1987;8(3):113–6.

174. Josephson A, Gombert ME, Sierra MF, Karanfil LV, Tansino GF. The relationship between intravenous fluid contamination and the frequency of tubing replacement. Infect Control 1985;6:367–70.

175. Maki DG, Botticelli JT, LeRoy ML, Thielke TS. Prospective study of replacing administration sets for intravenous therapy at 48- vs 72-hour intervals: 72 hours is safe and cost-effective. JAMA 1987;258:1777–81.

176. McKee KT, Melly MA, Greene HL. Gram-negative bacillary sepsis associated with use of lipid emulsion in parenteral nutrition. Am J Dis Child 1979;133:649–50.

177. Jarvis WR, Highsmith AK, Allen JR, Haley RW. Polymicrobial bacteremia associated with lipid emulsion in a neonatal intensive care unit. Pediatr Infect Dis 1983;2:203–8.

178. Melley MA, Meng HC, Schaffner W. Microbial growth in lipid emulsions used in parenteral nutrition. Arch Surg 1975;110:1479–81.

179. Crocker KS, Noga R, Filibeck DJ, et al. Microbial growth comparisons of five commercial parenteral lipid emulsions. J Parenter Enteral Nutr 1984;8:391–5.

180. McArthur BJ, Hargiss C, Schoenknecht FD. Stopcock contamination in an ICU. Am J Nurs 1975;75:96–7.

181. Walrath JM, Abbott NK, Caplan E, Scalan E. Stopcock: Bacterial contamination in invasive monitoring systems. Heart Lung 1979;8:100–04.

182. Inque Y, Nez R, Matsuda H, et al. Prevention of catheter-related sepsis during parenteral nutrition: effect of a new connection device. J Parenter Enteral Nutr 1992;16:581–5.

183. Crow S, Conrad SA, Chaney-Rowell C, King JW. Microbial contamination of arterial infusions used for hemodynamic monitoring: a randomized trial of contamination with sampling through conventional stopcocks versus a novel closed system. Infect Control 1989;10:557–61.

184. Miller JJ, Bahman V, Mathru M. Comparison of the sterility of long-term central venous catheterization using single-lumen, triple-lumen, and pulmonary artery catheters. Crit Care Med 1984;12:634–7.

185. Ullman RF, Gurevich I, Schoch PE, Cunha BA. Colonization and bacteremia related to duration of triple-lumen intravascular catheter placement. Infect Control 1990;18:201–7.

186. Cobb DK, High KP, Sawyer RG, et al. A controlled trial of scheduled replacement

of central venous and pulmonary artery catheters. N Engl J Med 1992;327 (15):1062–8.

187. Eyer S, Brummitt C, Crossley K, et al. Catheter-related sepsis: Prospective, randomized study of three different methods of long-term catheter maintenance. Crit Care Med 1990;18:1073–9.

188. Michel LA, Bradpiece HA, Randour P, Pouthier F. Safety of central venous catheter change over a guidewire for suspected catheter-related sepsis: a prospective randomized trial. Int Surg 1988;73:180–6.

189. Newsome HH Jr, Armstrong CW, Mayhall CG, et al. Mechanical complications from insertion of subclavian venous feeding catheters: Comparison of de novo percutaneous venipuncture to change of catheter over guidewire. J Parenter Enteral Nutr 1984;8:560–2.

190. Snyder RH, Archer FJ, Endy T, et al. Catheter infection: a comparison of two catheter maintenance techniques. Ann Surg 1988;208:651–3.

191. Ayliffe GAJ, Babb JR, Davies JG, et al. Hand disinfection: A comparison of various agents in laboratory and ward studies. J Hosp Infect 1988;11:226–43.

192. Rotter M, Koller W, Wewalka G. Povidone-iodine and chlorhexidine gluconate containing detergents for disinfection of hands. J Hosp Infect 1980;1:149–58.

193. Maki DG, Ringer M, Alvarado CJ. Prospective randomized trial of povidone-iodine, alcohol, and chlorhexidine for prevention of infection associated with central venous and arterial catheters. Lancet 1991;338:339–43.

194. Shapiro JM, Bond EL, Garman JK. Use of a chlorhexidine dressing to reduce microbial colonization of epidural catheters. Anesthesiology 1990;73:625–31.

195. Strand CL, Wajsbort RR, Sturmann K. Effect of iodophor vs iodine tincture skin preparation on blood culture contamination rate. JAMA 1993;269:1004–6.

196. Moran JM, Atwood RP, Rowe MI. A clinical and bacteriologic study of infections associated with venous cutdowns. N Engl J Med 1965;272:554–60.

197. Norden CW. Application of antibiotic ointment to the site of venous catheterization: A controlled trial. J Infect Dis 1969;120:611–15.

198. Zinner SH, Denny-Brown BC, Braun P, Burke JP, Toala P, Kass EH. Risk of infection with indwelling intravenous catheters: effect of application of antibiotic ointment. J Infect Dis 1969;120:616–19.

199. Jerrad MM, Freeman JB. The effects of antibiotic ointments and antiseptics on the skin flora beneath subclavian catheter dressings during intravenous hyperalimentation. J Surg Res 1977;22:521–6.

200. Maki DG, Band JD. A comparative study of polyantibiotic and iodophor ointment in prevention of vascular catheter-related infection. Am J Med 1981;70:739–44.

201. Flowers RH, Schwenzer KJ, Kopel RF, Fisch MJ, Tucker SI, Farr BM. Efficacy of an attachable subcutaneous cuff for the prevention of intravascular catheter-related infection. A randomized, controlled trial. JAMA 1989;261:878–83.

202. Reagan DR, Doebbeling BN, Pfaller MA, et al. Elimination of coincident

Staphylococcus aureus nasal and hand carriage with intranasal application of mupirocin calcium ointment. Ann Intern Med 1991;114:101–6.

203. Hill RLR, Fisher AP, Ware RJ, et al. Mupirocin for the reduction of colonization of internal jugular cannulae—a randomized controlled trial. J Hosp Infect 1990;15:311-21.

204. Smith MD, Sanghrijka M, Lock S. Mupirocin-resistant Staphylococcus aureus. Lancet 1987;2:1471–3.

205. Smith GE, Kennedy CTC. Staphylococcus aureus resistant to mupirocin. J Antimicrob Chemother 1988;21:141–2.

206. Noble WC, Rahman M, Cookson B, et al. Transferable mupirocin-resistance. J Antimicrob Chemother 1988;22:771–2.

207. Katich M, Band J. Local infection of the intravenous-cannulae wound associated with transparent dressings. J Infect Dis 1985;151:971–2.

208. Dickerson N, Horton P, Smith S, Rose RC III. Clinically significant central venous catheter infections in a community hospital: association with type of dressing. J Infect Dis 1989;160:720–1.

209. Conly JM, Grieves K, Peters B. A prospective, randomized study comparing transparent and dry gauze dressings for central venous catheters. J Infect Dis 1989;159:310–9.

210. Powell C, Regan C, Fabri PJ, Ruberg RL. Evaluation of Opsite catheter dressings for parenteral nutrition: a prospective, randomized study. J Parenter Enteral Nutr 1982;6:43–6.

211. Ricard P, Martin R, Marcoux JA. Protection of indwelling vascular catheters: incidence of bacterial contamination and catheter-related sepsis. Crit Care Med 1985;13:541–3.

212. Young GP, Alexeyeff M, Russell D, Thomas RJS. Catheter sepsis during parenteral nutrition: the safety of long-term OpSite dressings. J Parenter Enteral Nutr 1988;12:365–70.

213. Maki DG, Stolz S, Wheeler S. A prospective, randomized, three-way clinical comparison of a novel, highly-permeable polyurethane dressing with 206 Swan Ganz pulmonary artery catheters: Opsite IV 3000 vs Tegaderm vs gauze and Tape. I. Cutaneous colonization under the dressing, catheter-related infection. Maki DG, ed. In: Improving Catheter Site Care. London: Royal Society of Medicine Services, 1991.

214. Hoffman KK, Weber DJ, Samsa GP, Rutala WA. Transparent polyurethane film as an intravenous catheter dressing: A meta-analysis of the infection risks. JAMA 1992;267:2072–6.

215. Quinlan A. In vivo assessment of microbial proliferation under Opsite IV 3000, Tegaderm and Tegaderm Plus, with and without serum. In: Proceedings and Abstracts of the Third International Meeting of the Hospital Infection Society. London: Hospital Infection Society.

216. Babycos CR, Barracos A, Mancuso J, Turner-Marse T. Collodion as a safe, cost-effective dressing for central venous catheters. South Med J 1990;83:1286–87.

217. Rusho WJU, Batt JN. Effect of filtration on complications of postoperative

intravenous therapy. Am J Hosp Pharm 1979;36:1355–6.

218. Allcutt DA, Lort D, McCollum CN. Final inline filtration for intravenous infusions: a prospective study. Br J Surg 1983;70:111–3.

219. Falchuk KH, Peterson L, McNeil BJ. Microparticulate-induced phlebitis: Its prevention by in-line filtration. N Engl J Med 1985;312:78–82.

220. Maddox RR, John JF Jr, Brown LL, Smith CE. Effect of inline filtration on postinfusion phlebitis. Clin Pharm 1983;2:58–61.

221. Turco SJ, Davis NM. Particulate matter in intravenous infusion fluids. Am J Hosp Pharm 1973;30:611–3.

222. Baumgartner TG, Schmidt GL, Thakker KM, et al. Bacterial endotoxin retention by inline intravenous filters. Am J Hosp Pharm 1986;43:681–4.

223. Butler LD, Munson JM, Deluca PP. Effect of inline filtration on the potency of low-dose drugs. Am J Hosp Pharm 1980;37:935–41.

224. Freeman JB, Litton AA. Preponderance of gram-positive infections during parenteral alimentation. Surg Gynecol Obstet 1974;139:905–8.

225. Maki DG, Cobb L, Garman JK, Shapiro JM, Ringer M, Helgerson RB. An attachable silver-impregnated cuff for prevention of infection with central venous catheters: A prospective randomized multicenter trial. Am J Med 1988;85:307–14.

226. Trooskin SZ, Donetz AP, Harvey RA, Greco RS. Prevention of catheter sepsis by antibiotic bonding. Surgery 1985;97:547–51.

227. Sherertz RJ, Carruth WA, Hampton AA, Byron MP, Solomon DD. Efficacy of antibiotic-coated catheters in preventing subcutaneous Staphylococcus aureus infection in rabbits. J Infect Dis 1993;167:98–106.

228. Kamal GD, Pfaller MA, Rempe LE, Jebson PJ. Reduced intravascular catheter infection by antibiotic bonding. A prospective, randomized, controlled trial. JAMA 1991;265:2364–8.

229. Tomford JW, Hershey CO, McLaren JCE, Porter DK, Cohen DI. Intravenous therapy team and peripheral venous catheter-associated complications: A prospective control study. Arch Intern Med 1984;144:1191–4.

230. Nelson DB, Kein CL, Mohr B, Frank S, Davis SD. Dressing changes by specialized personnel reduce infection rates in patients receiving central venous parenteral nutrition. J Parenter Enteral Nutr 1986;10:220–2.

231. Faubion WC, Wesley JR, Khaldi N, et al. Total parenteral nutrition catheter sepsis: Impact of the team approach. J Parenter Enteral Nutr 1986;10:642–5.

232. Bock SN, Lee RE, Fisher B, et al. A prospective randomized trial evaluating prophylactic antibiotics to prevent triple-lumen catheter-related sepsis in patients treated with immunotherapy. J Clin Oncol 1990;8(1):161–9.

233. Al-Sibai MB. The value of prophylactic antibiotics during insertion of long-term indwelling silastic right atrial catheters in cancer patients. Cancer 1987;60:1891–5.

234. McKee R. Does antibiotic prophylaxis at the time of catheter insertion reduce the

incidence of catheter-related sepsis in intravenous nutrition? J Hosp Infect 1985;6:419–25.

235. Ranson MR, Oppenheim BA, Jackson A, Kamthan AG, Scarffe JH. Double-blind placebo controlled study of vancomycin prophylaxis for central venous catheter insertion in cancer patients. J Hosp Infect 1990;15:95–102.

236. Schwartz C, Henrickson KJ, Roghmann K, Powell K. Prevention of bacteremia attributed to luminal colonization of tunneled central venous catheters with vancomycin-susceptible organisms. J Clin Oncol 1990;8:1591–7.

237. Kacica MA, Horgan MJ, Ochoa L. Prevention of gram-positive sepsis in neonates weighing less than 1500 grams. J Pediatr 1994;125:253–8.

238. Spafford PS, Sinkin RA, Cox C, Reubens L, Powell KR. Prevention of central venous catheter-related coagulase-negative staphylococcal sepsis in neonates. J Pediatr 1994;125:259–63.

239. Raad II, Luna M, Khalil SA, Costerton JW, Lam C, Bodey GP. The relationship between the thrombotic and infectious complications of central venous catheters. JAMA 1994;271:1014–6.

240. Ashton J, Gibson V, Summers S. Effects of heparin versus saline solution on intermittent infusion device irrigation. Heart Lung 1990;19:608–12.

241. Weber DR. Is heparin really necessary in the lock and, if so, how much? DICP Ann Pharmacother 1991;25:399–407.

242. Root JL. Inhibitory effect of disodium EDTA upon the growth of *Staphylococcus epidermidis* in vitro: relation to infection prophylaxis of Hickman catheters. Antimicrob Agents Chemother 1988;32:1627–31.

243. Heeger PS, Backstrom JT. Heparin flushes and thrombocytopenia. Ann Intern Med 1986;19:69–72.

244. Passannante A, Macik BG. Case report: The heparin flush syndrome: A cause of iatrogenic hemorrhage. Am J Med Sci 1988;296:71–3.

245. Rhodes GR, Dixon RH, Silver D. Heparin induced thrombocytopenia with thrombotic and hemorrhagic manifestations. Surg Gynecol Obstet 1973;136:409–16.

246. Silver D, Kapsch DN, Tsoi EK. Heparin-induced thrombocytopenia, thrombosis, and hemorrhage. Ann Surg 1983;198:301–4.

247. Sketch MH. Use of percutaneously inserted venous catheters in coronary care units. Chest 1972;62:684–9.

248. Bassan MM. Prevention of lidocaine-infusion phlebitis by heparin and hydrocortisone. Chest 1983;84:439–41.

249. Khawaja HT. Effect of transdermal glyceryl trinitrate on the survival of peripheral intravenous infusions: a double-blind prospective clinical study. Br J Surg 1988;75:1212–5.

250. Wright A. Use of transdermal glyceryl trinitate to reduce failure of intravenous infusion due to phlebitis and extravasation. Lancet 1985;2:1148–50.

251. Woodhouse CR. Movelat in the prevention of infusion thrombophlebitis. Br Med J 1979;1:454–5.

252. O'Brien BJ, Buxton MJ, Khawaja HT. An economic evaluation of transdermal

glycerly trinitrate in the prevention of intravenous infusion failure. J Clin Epidemiol 1990;43:757–63.

253. Adams KS, Zehrer CL, Thomas W. Comparison of a needleless system with conventional heparin locks. Infect Control Hosp Epidemiol 1993;21:263–9.

254. Danzig LE, Short L, Collins K, et al. Bloodstream infections associated with a needleless intravenous infusion system and total parenteral nutrition. Infect Control Hosp Epidemiol 1995;16(part 2):22.

255. Longfield R, Longfield J, Smith LP, Hyams KC, Strohmer ME. Multidose medication vial sterility: An in-use study and a review of the literature. Infect Control 1984;5:165–9.

256. Nakashima AK, Highsmith AK, Martone WJ. Survival of *Serratia marcescens* in benzalkonium chloride and in multiple-dose medication vials: relationship to epidemic septic arthritis. J Clin Microbiol 1987;25:1019–21.

257. Kothari T, Reyes MP, Brooks N, Brown MJ, Lerner AM. *Pseudomonas cepacia* septic arthritis due to intra-articular injections of methylprednisolone [letter]. Can Med Assoc J 1977;116:1230–5.

258. Highsmith AK. Growth of nosocomial pathogens in multiple-dose parenteral medication vials. J Clin Microbiol 1982;15:1024–8.

259. Alter MJ, Ahtone J, Maynard JE. Hepatitis B virus transmission associated with a multiple-dose vial in a hemodialysis unit. Ann Intern Med 1983;99:330–3.

260. Herruzo-Cabrera R, Garcia-Caballero J, Vera Cortes ML, et al. Growth of microorganisms in parenteral nutrient solutions. Am J Hosp Pharm 1984;41:1178–80.

261. Scheckelhoff DJ, Mirtallo JM, Ayers LW, Visconti JA. Growth of bacteria and fungi in total parenteral nutrient admixtures. Am J Hosp Pharm 1986;43:73–7.

262. Degleux G, Le Coutour X, Hecquard C, Oblin I. Septicemia caused by contaminated parenteral nutrition pouches: the refrigerator as an unusual cause. J Parenter Enteral Nutr 1991;15:474–5.

263. Llop JM, Mangues I, Perez JL, Lopez P, Tuban M. *Staphylococcus saprophyticus* sepsis related to total parenteral nutrition admixtures contamination. J Parenter Enteral Nutr 1993;17:575–7.

264. Snydman DR, Murray SA, Kornfeld SJ, Majka JA, Ellis CA. Total parenteral nutrition-related infections. Am J Med 1982;73:695–9.

265. Ryan JA, Abel RM, Abbott WA, et al. Catheter complication in parenteral nutrition. A prospective study of 200 consecutive patients. N Engl J Med 1974;290:757–61.

266. Vanhuynegem L, Parmentier P, Potvliege C. In place bacteriologic diagnosis of total parenteral nutrition catheter infection. Surgery 1988;103:174–7.

267. Keohane PP, Attrill H, Northover J, et al. Effect of catheter tunnelling and a nutrition nurse on catheter sepsis during parenteral nutrition: a controlled trial. Lancet 1983:1388–90.

268. Powell CR, Traetow MJ, Fabri PJ, Kudsk KA, Ruberg RL. Op-Site dressing study: A prospective randomized study evaluating povidone iodine ointment and

extension set changes with 7-day Op-Site dressings applied to total parenteral nutrition subclavian sites. J Parenter Enteral Nutr 1985;9:443–6.

269. Rannem T, Ladefoged K, Hegnhoj F, Hylander Moller E, Bruun B, Farnum S. Catheter-related sepsis in long-term parenteral nutrition with Broviac catheters. An evaluation of different disinfectants. Clinical Nutrition 1990;9:131–6.

270. Maki DG, McCormack KN. Defatting catheter insertion sites in total parenteral nutrition is no value as an infection control measure. Am J Med 1987;83:833–40.

271. Palidar PJB, Simonowitz DA, Oreskovich MR, et al. Use of Op-Site as an occlusive dressing for total parenteral nutrition catheters. J Parenter Enteral Nutr 1982;6:150–1.

272. Uldall PR, Dyck RF, Woods F, et al. A subclavian catheter for temporary vascular access for hemodialysis and plasmapheresis. Dialysis Transplant 1979;296:1305–9.

273. Tokars JI, Alter MS, Favero MS, Moyer LA, Bland LA. National surveillance of hemodialysis associated disease in the United States, 1990. ASAIO J 1993;39:71–80.

274. Pezzarossi HE, Ponce de Leon S, Calva JJ, Lazo de la Vega SA, Ruiz-Palacios GM. High incidence of subclavian dialysis catheter-related bacteremias. Infect Control 1986;7:596–9.

275. Keane WF, Shapiro FL, Raij L. Incidence and type of infection occurring in 445 chronic hemodialysis patients. Trans Am Soc Artif Intern Organ 1977;23:41–6.

276. Sherertz RJ, Falk RJ, Huffman KA, Thomann CA, Mattern WD. Infections associated with subclavian Uldall catheters. Arch Intern Med 1983;143:52–6.

277. Cheesbrough JS, Finch RG, Burden RP. A prospective study of the mechanisms of infection associated with hemodialysis catheters. J Infect Dis 1986;154:579–89.

278. Almirall J, Gonzalez J, Rello J, et al. Infection of hemodialysis catheters: incidence and mechanisms. Am J Nephrol 1989;9:454–9.

279. Blake PG, Huraib S, Uldall PR. The use of dual lumen jugular venous catheters as definitive long term access for haemodialysis. Int J Artif Organs 1990;13:26–31.

280. Bour ES, Weaver AS, Yang HC, Gifford RRM. Experience with the double-lumen silastic catheter for hemoaccess. Gynecol Obstet 1990;171:33–9.

281. Shusterman NH, Kross K, Muffen JL. Successful use of double-lumen, silicone rubber catheters permanent hemodialysis access. Kidney Int 1989;35:887–90.

282. Shaffer D, Madras PN, Williams ME, D'Elia JA, Kaldany A, Monaco AP. Use of Dacron cuffed silicone catheters as long-term hemodialysis access. ASAIO J 1992;38:55–8.

283. Kong NCT, Morad Z, Suleiman AB. Subclavian catheters as temporary vascular access. Sing Med J 1989;261–2.

284. Dobkin JF, Miller MH, Steigbigel NH. Septicemia in patients on chronic hemodialysis. Ann Intern Med 1978;88:28–33.

285. Vanherweghem JL, Dhaene M, Goldman M, et al. Infections associated with subclavian dialysis catheters: the key role of nurse training. Nephron 1986;42:116–9.

286. Moss AH, Vasilakis C, Holley JL, Foulks CJ, Pillai K, McDowell DE. Use of a silicone dual-lumen catheter with a Dacron cuff as a long-term vascular access for hemodialysis patients. Am J Kidney Dis 1990;16:211–5.

287. Watson AR, Bahoric A, Wesson D. A central venous (WBW) catheter for multipurpose vascular access in children. Artif Organs 1986;10:59–61.

288. Canaud B, Beraud JJ, Joyeux H, Mion C. Internal jugular vein cannulation using two silastic catheters. Nephron 1986;43:133–8.

289. Donnelly PK, Hoenich NA, Lennard TWJ, Proud G, Taylor RMR. Surgical management of long-term central venous access in uraemic patients. Nephrol Dial Transplant 1988;3:57–65.

290. Howell PB, Walter PE, Donowitz GR, Farr BM. Risk factors for infection of adult patients with cancer who have tunneled central venous catheters. Cancer 1995;75:1367–75.

291. Tapson JS, Uldall PR. Avoiding deaths from subclavian cannulation for haemodialysis. Int J Artif Organs 1983;6:227–30.

292. Barton BR, Hermann G, Weil R. Cardiothoracic emergencies associated with subclavian hemodialysis catheters. JAMA 1983;250:2600–62.

293. Tapson JS, Uldall PR. Fatal hemothorax caused by a subclavian hemodialysis catheter. Arch Intern Med 1984;144:1685–7.

294. Brady HR, Fitzcharles B, Goldberg H, et al. Diagnosis and management of subclavian vein thrombosis occurring with subclavian cannulation for haemodialysis. Blood Purif 1989;7:210–7.

295. Schwab SJ, Buller GL, McCann RL, Bollinger RR, Stickel DL. Prospective evaluation of a Dacron-cuffed hemodialysis catheter for prolonged use. Am J Kidney Dis 1988;11:166–9.

296. Pourchez T, Moriniere P, Fournier A, Pietri J. Use of a Perm-cath (Quinton) catheter in uraemic patients in whom the creation of conventional vascular access for haemodialysis is difficult. Nephron 1989;53:297–302.

297. Kaplowitz LG, Comstock JA, Landwehr DM, et al. A prospective study of infections in hemodialysis patients: patient hygiene and other risk factors for infection. Infect Control Hosp Epidemiol 1988;8:534–41.

298. Meyrier A, Chevet D, Marsac J, Leroux-Robert C, Sraer JD, Scetbon V. Staphylococcemias chez las malades hemodialyses. Nouv Presse Med 1973;2:2379–83.

299. Foissac-Gegoux P, Dumont A. Septicemias au cours du traitement par hemodialyse periodique. Nouv Presse Med 1974;3:151.

300. Cappello M, De Pauw L, Bastin G, et al. Central venous access for hemodialysis using the Hickman catheter. Nephrol Dial Transplant 1989;4:988–92.

301. Yu VL, Goetz A, Wagener M, et al. Staphylococcus aureus nasal carriage and infection in patients on hemodialysis: efficacy of antibiotic prophylaxis. N Engl J Med 1986;315:91–6.

302. Kirmani S, Tuazon CU, Murray HW, Parrish AE, Sheagran JN. Staphylococcal aureus carriage rate of patients receiving long-term hemodialysis. Arch Intern Med 1978;138:1657–79.

303. Ralston AJ, Harlow GR, et al. Infections of Scribner and Brescia arteriovenous shunts. Br Med J 1971;3:408–9.

304. Levin A, Mason AJ, Jindal KK, Fong IW, Goldstein MB. Prevention of hemodialysis subclavian vein catheter infections by topical povidone-iodine. Kidney Int 1991;40:934–8.

305. Uldall PR et al. The subclavian cannula: Temporary vascular access for hemodialysis when long-term peritoneal dialysis has to be interrupted. Peritoneal Dial Bull 1981;1:97–9.

306. Carlisle EJF, Blake P, McCarthy F, Vas S, Uldall R. Septicemia in long-term jugular hemodialysis catheters: eradicating infection by changing the catheter over a guidewire. Int J Artif Organs 1991;14:150–3.

307. Farber BF. The multi-lumen catheter: proposed guidelines for its use. Infect Control Hosp Epidemiol 1988;9:206–8.

308. Graeve AH, Carpenter CM, Schiller WR. Management of central venous catheters using a wire introducer. Am J Surg 1981;142:752–5.

309. Domoto DT, Kennedy DJ. Antibiotic treatment of chronic central venous hemodialysis catheter infection without catheter removal. Int J Artif Organs 1985;10:239–40.

310. Freeman J, Platt R, Sidebottom DG, Laclair JM, Epstein MF, Goldmann DA. Coagulase-negative staphylococcal bacteremia in the changing neonatal intensive care unit population. JAMA 1987;258:2548–52.

311. Garland JS, Dunne WM, Havens P, et al. Peripheral intravenous catheter complications in critically ill children: a prospective study. Pediatrics 1992;89:1145–50.

312. Garland JS, Nelson DB, Cheah T, Hennes HH, Johnson TM. Infectious complications during peripheral intravenous therapy with Teflon catheters: a prospective study. Pediatr Infect Dis J 1987;6:918–21.

313. Batton DG, Maisels MJ, Appelbaum P. Use of peripheral intravenous cannulas in premature infants: A controlled study. Pediatrics 1982;70:487–90.

314. Furfaro S, Gauthier M, Lacroix J, Nadeau D, Lefleur L, Mathews S. Arterial catheter-related infections in children: a 1-year cohort analysis. Am J Dis Child 1991;145:1037–42.

315. Adam RD, Edwards LD, Becker CC, Schrom HM. Semiquantitative cultures and routine tip cultures on umbilical catheters. J Pediatr 1982;100:123–6.

316. Danker WM, Spector SA, Fierer J, et al. Malassezia fungemia in neonates and adults: complication of hyperalimentation. Rev Infect Dis 1987;9:743–53.

317. Garcia CR, Johnston BL, Corvi G, et al. Intravenous catheter-associated Malassezia furfur fungemia. Am J Med 1987;83:790–92.

318. Long JG, Keyserling HL. Catheter-related infection in infants due to unusual lipophilic yeast—Malassezia furfur. Pediatrics 1985;76:896–900.

319. Alpert G, Bell LM, Campos JM. Malassezia furfur fungemia in infancy. Clin Pediatr 1987;26:528–31.

320. Bertone SA, Fisher MC, Mortensen JE. Quantitative skin cultures at potential catheter sites in neonates. Infect Control Hosp Epidemiol 1994;15:315–8.

321. Gaynes RP, Martone WJ, Culver DH, et al. Comparison of rates of nosocomial infections in neonatal intensive care units in the United States. Am J Med 1991;91 (suppl 3B):192S–6S.

322. Cronin WA, Germanson TP, Donowitz LG. Intravascular catheter colonization and related bloodstream infection in critically ill neonates. Infect Control Hosp Epidemiol 1990;11:301–8.

323. Nelson DB, Garland JS. The natural history of Teflon catheter associated phlebitis in children. Am J Dis Child 1987;141:1090–2.

324. Landers S, Moise AA, Fraley JK, Smith EO, Baker CJ. Factors associated with umbilical catheter-related sepsis in neonates. Am J Dis Child 1991;145:675–80.

325. Krauss AN, Albert RF, Kannan MM. Contamination of umbilical catheters in the newborn infant. J Pediatr 1970;77:965–9.

326. Balagtas RC, Bell CE, Edwards LD, Levin S. Risk of local and systemic infections associated with umbilical vein catheterization: A prospective study in 86 newborn patients. Pediatrics 1971;48:359–67.

327. Bard H, Albert G, Teasdale F, Doray B, Martineau B. Prophylactic antibiotics in chronic umbilical artery catheterization in respiratory distress syndrome. Arch Dis Child 1973;48:630–5.

328. Mayhall CG. Diagnosis and management of infections of implantable devices used for prolonged venous access. In: Remington JS, Swartz MN, eds. Current Clinical Topics In Infectious Diseases. v. 12. Boston: Blackwell Scientific Publications, 1992:83–110.

329. LaQualglia MP, Lucas A, Thaler HT, Freidlander-Klar H, Exelby PR, Groeger JS. A prospective analysis of vascular access device-related infections in children. J Pediatr Surg 1992;27:840–2.

330. Wiener ES, McGuire P, Stolar CJH, et al. The CCSG prospective study of venous access devices: an analysis of insertions and causes for removal. J Pediatr Surg 1992;27:155–64.

331. Sola JE, Stone MM, Wise B, Columbani PM. Atypical thrombotic and septic complications of totally implantable venous access devices in patients with cystic fibrosis. Pediatr Pulmonol 1992;14:239–42.

332. Johnson PR, Decker MD, Edwards KM, et al. Frequency of Broviac catheter infections in pediatric oncology patients. J Infect Dis 1984;154:570–8.

333. Mulloy RH, Jadavji T, Russell ML. Tunneled central venous catheter sepsis: risk factors in a pediatric hospital. J Parenter Enteral Nutr 1991;15:460–3.

334. Gorelick MH, Owen WC, Seibel NL, Reaman GH. Lack of association between neutropenia and the incidence of bacteremia associated with indwelling central venous catheters in febrile pediatric cancer patients. Pediatr Infect Dis J 1991;10:506–10.

335. Mirro J, Rao BN, Stokes DC, et al. A prospective study of Hickman/Broviac

catheters and implantable ports in pediatric oncology patients. J Clin Oncol 1989;7:214–22.

336. Stenzel JP, Green TP, Fuhrman BP, Carlson PE, Marchessault RP. Percutaneous central venous catheterization in a pediatric intensive care unit: A survival analysis of complications. Crit Care Med 1989;17:984–8.

337. Conly JM, Hill S, Ross J, Lertzman J, Louie TJ. Handwashing practices in an intensive care unit: the effects of an educational program and its relationship to infection rates. Am J Clin Path 1989;17:330–9.

338. Seto WH, Ching TY, Yuen KY, Chu YB, Seto WL. The enhancement of infection control in-service education by ward opinion leaders. Am J Clin Path 1991;19:86–91.

339. Freeman J, McGowan JE. Methodologic issues in hospital epidemiology. I. Rates, case finding and interpretation. Rev Infect Dis 1981;3:658–67.

340. Haley RW, Culver DH, White JW, et al. The efficacy of infection surveillance and control programs in preventing nosocomial infections in US hospitals. Am J Epidemiol 1985;121:182–205.

341. Josephson A, Karanfil L, Alonso H, Watson A, Bilght J. Risk-specific nosocomial infection rates. Am J Med 1991;91(suppl 3B):131S–7S.

342. Centers for Disease Control and Prevention. Update: Universal precautions for prevention of transmission of HIV, hepatitis B, and other bloodborne pathogens in healthcare settings. MMWR 1988;24:377–82,387–88.

343. Cortopassi RF, Kikugawa CA. Evaluation of antiseptics in the preparation of intravenous admixtures. Am J Hosp Pharm 1977;34:1193–6.

344. Plott RT, Wagner RF, Tyring SK. Iatrogenic contamination of multidose vials in simulated use: a reassessment of current patient injection technique. Arch Dermatol 1990;126:1441–4.

345. Lutz CT, Bell CE, Wedner HJ, Krogstad DJ. Allergy testing of multiple patients should no longer be performed with a common syringe. N Engl J Med 1984;310:1335–7.

346. Shulan DJ, Weiler JM, Koontz F, Richerson HB. Contamination of intradermal skin test syringes. J Allergy Clin Immunol 1985;76:226–7.

347. Keammerer D, Mayhall CG, Hall GO, Pesko LJ, Thomas RB. Microbial growth patterns in intravenous fat emulsions. Am J Hosp Pharm 1983;40:1650–3.

348. D'Angio RG, Riechers KC, Gilsdorf RB, Constantino JM. Effect of the mode of lipid administration on parenteral nutrition-related infections. Ann Pharmacother 1992;26:14–7.

349. ASHP. ASHP therapeutic position statement on the institutional use of 0.9% sodium chloride injection to maintain patency of peripheral indwelling intermittent infusion devices. Am J Hosp Pharm 1994;51:1572–4.

350. Gyves J, Ensminger W, Niederhuber J, et al. Totally-implanted system for intravenous chemotherapy in patients with cancer. Am J Med 1982;73:841–5.

351. Shulman RJ, Smith EO, Rahman S, Gardner P, Reed T, Mahoney D. Single- vs double-lumen central venous catheters in pediatric oncology patients. Am J Dis Child 1988;142:893–5.

352. Nahata MC, King DR, Powell DA, Marx SM, Ginn-Pease ME. Management of catheter-related infections in pediatric patients. J Parenter Enteral Nutr 1988;12:58–9.

353. Felices FJ, Hernandez JL, Ruiz J, Meseguer J, Gomez JA, Molina E. Use of the central venous pressure catheter to obtain blood cultures. Crit Care Med 1979;7:78–9.

354. Tafuro P, Colbourn D, Gurevich I, et al. Comparison of blood cultures obtained simultaneously by venipuncture and from vascular lines. J Hosp Infect 1986;7:283–8.

355. Bryant JK, Strand CL. Reliability of blood cultures collected from intravascular catheter versus venipuncture. Am J Clin Pathol 1987;88:113–6.

356. Wormser GP, Onorato IM, Preminger TJ, Culver D, Martone WJ. Sensitivity and specificity of blood cultures obtained through intravascular catheters. Crit Care Med 1990;18:152–6.

357. Powell C, Kudsk KA, Lulich PA, Mandelbaum JA, Fabri PJ. Effect of frequent guidewire changes on triple-lumen catheter sepsis. J Parenter Enteral Nutr 1988;12:462–4.

[FR Doc. 95–23550 Filed 9–26–95; 8:45 am]

BILLING CODE 4163–18–P